UNITED STATES AIR FORCE CIVIL ENGINEER

INSTALLED UNDERWING FIRE SUPPRESSION
AND
MOBILE AUTOMATIC FOAM FIRE EXTINGUISHER
IN AIR FORCE HANGARS

OPERATIONAL RISK MANAGEMENT (ORM)
ANALYSIS REPORT

OPR: HQ AFCESA/CESM
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EXECUTIVE SUMMARY

BACKGROUND

During the 1996 Air Force Civil Engineer Worldwide Conference, HQ USAF/ILE tasked HQ AFCESA to conduct a bottom-up review of the Air Force Fire Protection Program. As part of this review, HQ AFCESA was tasked to review the aircraft hangar fire protection standards requiring Aqueous Film Forming Foam (AFFF) systems, based on the fact that the Air Force now uses the less volatile JP-8 aircraft fuel in lieu of JP-4. HQ AFCESA briefed the 1997 Air Force Civil Engineer Worldwide Conference with the results of the review. Conference attendees approved the recommended revised concept for aircraft for hangar fire protection. HQ AFCESA was further tasked by the 1997 attendees to evaluate alternative aircraft hangar fire protection systems, including portable automatic extinguisher systems in combination with water suppression systems, using the operational risk management (ORM) process.

METHODOLOGY AND OBJECTIVE

HQ AFCESA formed an eight-member team representing aircraft maintenance (HQ USAF/ILMM), aircraft acquisition (SAF/AQRE), fire operations (AFCESA/CEXF), fire protection and cost engineering (AFCESA/CESM/CESC), research (AFRL/MLQC), and risk analysis (Applied Research Associates, Inc.), to evaluate a prototype mobile automatic foam fire extinguisher (MAFFE). The team used established risk assessment methodology to determine the feasibility of the MAFFE for fire protection in Air Force hangars. The team also assessed the hazards and risks of the current underwing fire suppression systems. The MAFFE system and the underwing fire suppression system were evaluated individually against current operational requirements, rather than against each other.

The ORM team reviewed existing hangar fire test data and Air Force hangar fire loss records; contracted with Hughes Associates to conduct fire tests on water-only overhead suppression systems in hangars and on the prototype MAFFE; computed life cycle cost for the installed underwing systems and MAFFE using standard cost methodology; surveyed the field for operational requirements; and reviewed the current National Fire Protection Association (NFPA) criteria for hangars. The ORM objective was to realize savings in hangar fire protection life cycle costs while meeting mission support requirements at an acceptable risk.

The current Air Force hangar fire protection requirement is established by Department of Defense Military Handbook (MIL-HDBK) 1008C and is a modification of NFPA hangar criteria. Engineering Technical Letter (ETL) 98-7, *Fire Protection Engineering Criteria – New Aircraft Facilities*), and ETL 98-8, *Fire Protection Engineering Criteria – Existing Aircraft Facilities*, provide fire protection engineering technical criteria governing Air Force hangers. These ETLs provide the technical guidance for the design and construction of fire protection systems protecting adjacent aircraft and the facility (at a slightly reduced level of protection than required by NFPA standards for commercial aircraft).

AUTHORITY AND REFERENCES

The risk management process used to conduct this analysis is contained in Air Force Instruction (AFI) 91-213, *Operational Risk Management Program,* and Air Force Pamphlet (AFPAM) 91-215, *Operational Risk Management Techniques and Tools*. Supporting information is contained in the National Fire Protection Association Standard 409, *Aircraft Hangars*, and in the Society of Fire Protection Engineers' *Handbook of Fire Protection Engineering,* Section 4, “Fire Risk Calculations.”

PRINCIPLES OF OPERATIONAL RISK MANAGEMENT

The following operational risk management principles guided the analysis:

- Accept no unnecessary risk
- Make risk decisions at the appropriate level
- Accept risk when benefits outweigh the costs

RISK ANALYSIS PROCESS

The risk analysis process includes six steps:

(1) Identify the hazard

(2) Assess the risk
  - Exposure
  - Severity
  - Probability of Occurrence

(3) Analyze risk control measures

(4) Make control decisions

(5) Implement risk controls

(6) Supervise and review

CONCLUSION

The team consensus at the completion of the ORM analysis was that the MAFFE concept is not acceptable for Air Force hangar fire protection, for the following reasons:

- Life cycle cost of the MAFFE exceeds the cost of AFFF installed underwing protection systems by factors of 1.6 to 3.4, depending on existing hangar conditions. While the initial installed cost of the MAFFE varied from 0.4 to 0.9 times the cost of installed underwing AFFF systems, the increased operation, maintenance, and operator training costs of the MAFFE rapidly negated the advantage over the life of the system. These costs do not include the health-related injury cost uniquely associated with the operation and maintenance of the MAFFE.

- MAFFE imposes unacceptable manpower burdens on the maintenance community. The results of the field survey reinforced this conclusion. Responsibility for the daily operation, maintenance, and movement of the MAFFE would have to be integrated into aircraft maintenance work processes, and associated life cycle costs would shift from an initial construction investment by civil engineers to long-term operations and personnel costs borne by the aircraft maintenance community.

- The operational characteristics of the MAFFE related to the limited agent discharge distance and coverage area for each unit required procurement and maintenance of an unacceptably large number of units.

- The critical positioning of the unit in relation to the specific type of protected aircraft poses a significant (extreme risk) hazard. No acceptable measure was identified to satisfactorily mitigate this hazard. The team considered marking the hanger floor, but because different type aircraft could be used in the same hanger, this was unacceptable. Even if only one type of aircraft were used in a hanger, floor marking would require the aircraft be maintained in exactly the same location. This was considered an unrealistic requirement to impose on the aircraft maintenance community that needs to retain flexibility of where an aircraft will be located in the hanger during maintenance.

RECOMMENDATION

- Recommend continued use of current Air Force criteria for hangar fire protection and fire department response as the best available solution for protecting existing Air Force assets.

STEP 1: IDENTIFY THE HAZARD

ACTION 1: MISSION/TASK ANALYSIS

The purpose of this risk analysis is to assess the hazards associated with using a Mobile Automatic Foam Fire Extinguisher (MAFFE) and the hazards associated with using an installed underwing fire suppression system in an Air Force aircraft hangar. Each system was evaluated individually against current operational requirements rather than against each other. The risk analysis sought to save Air Force funds while still providing a reasonable degree of protection for life and property in an aircraft hangar. It was based upon engineering principles, test data, and field experience.

The analyses for both the MAFFE and the underwing system used a hangar protected with an overhead water sprinkler system as the baseline, since neither system used alone would comply with national codes and standards, Air Force and Department of Defense (DOD) criteria, and standard engineering practice.

Current standards were evaluated for effectiveness and reliability. Hangar fire loss records were examined. Hughes Associates, under contract, conducted fire tests of overhead water sprinkler systems used alone, and of the effectiveness of the prototype MAFFE. A survey was conducted to determine operational parameters for aircraft hangar fire suppression systems. Finally, life cycle cost estimates were computed using standard cost methodology.

Employment of the MAFFE system was based on the concept-package (Attachment 1) developed following the Hughes Associates test program.

STEP 1: IDENTIFY THE HAZARD

ACTION 2: LIST HAZARDS

The risk analysis team used brainstorming techniques to list hazards for hangar fire protection when using either the MAFFE or the underwing system. These hazards were identified based upon experience and data reports. Following the 5-M model of AFPAM 91-215, the list provided a basic framework for analyzing systems and the relationships between elements working together to perform the mission. The results of the brainstorming sessions are displayed in Tables 1 and 2.

Table 1. Hangar Protection Hazards — MAFFE

CATEGORY	SUBCATEGORIES	HAZARDS/MAFFE
1. MAN	a. Selection	(1) Incompetent; inadequate/unsuccessful training
		(2) Does not understand procedural guidance for placement of MAFFE
	b. Performance	(1) Improper maintenance/procedures
		(2) Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)
		(3) Unaware of priory placement of equipment
		(4) Perceives equipment as unnecessary, redundant, or inconvenient

Table 1. Hangar Protection Hazards — MAFFE (Continued)

CATEGORY	SUBCATEGORIES	HAZARDS/MAFFE
1. MAN (Cont.)	b. Performance (Cont.)	(5) Workload negates importance of MAFFE handling
		(6) MAFFE struck by people performing other than mission activities (i.e.: sports, horseplay)
		(7) Personnel fail to reposition MAFFE for short duration jobs
		(8) Inadequate foam concentration used during recharge
		(9) Personnel injured by discharge spray
	c. Personal Factors	(1) Inadequate/inappropriate equipment use
		(2) Lack of consistency
		(3) Using MAFFE as a drying rack for personal rain gear
		(4) Intentional equipment activation/deactivation
2. MEDIA	a. Climatic	(1) Temperature requires placement of fans that block appropriate MAFFE placement
		(2) System components freeze
		(3) Fluids freeze in system
		(4) MAFFE battery charger vulnerable to climatic conditions
		(5) Equipment components vulnerable to temperature extremes
	b. Operational	(1) Maintenance person in aircraft when fire occurs
		(2) Delayed Fire Department response
		(3) MAFFE creates obstruction to routine work procedures
		(4) Foam pattern disrupted
		(5) MAFFE unable to control fire
		(6) Person driven into the fire by the force of the discharge
		(7) Person incurs back or foot injury when moving MAFFE
	c. Hygienic	(1) Hangar crowding
		(2) Conflicting maintenance operations
		(3) Blocked discharge
		(4) Unit improperly located

Table 1. Hangar Protection Hazards — MAFFE (Continued)

CATEGORY	SUBCATEGORIES	HAZARDS/MAFFE
2. MEDIA (Cont.)	d. Vehicular/Pedestrian	(1) Internal aircraft fires
		(2) Vehicular/AGE equipment fire
		(3) Fuel bowser location creates a spark hazard
		(4) Fires in adjacent support areas
3. MACHINE	a. Design	(1) Fuel ignites after draining into water drainage system
		(2) Inadequate foam coverage due to incorrect placement
		(3) MAFFE must be repositioned after each aircraft movement
		(4) MAFFE activated/deactivated erroneously by surrounding activity
		(5) Equipment requires visual observation to detect an inadvertent or erroneous shutdown
		(6) System components fail due to corrosion
		(7) System does not provide alarm other than to the local area
		(8) Not applicable this system
		(9) Environmental hazards require remediation after foam discharge
		(10) Inadequate agent - Failure to control fire
		(11) Insufficient agent - Failure to control fire
		(12) Limited discharge - Failure to control fire
	b. Maintenance	(1) Equipment malfunctions
		(2) Hazardous waste, personnel injured
		(3) Personnel injured, equipment damaged
		(4) Personnel injured
		(5) Equipment malfunction
		(6) Aircraft struck by MAFFE during normal operations
		(7) Personnel struck by MAFFE during normal operations
		(8) Personnel experiences electrical shock during maintenance
	c. Technical Data	(1) Equipment malfunction
		(2) Equipment malfunction
		(3) Equipment not used correctly
		(4) Aircraft not appropriately protected

Table 1. Hangar Protection Hazards — MAFFE (Continued)

CATEGORY	SUBCATEGORIES	HAZARDS/MAFFE
4. MANAGEMENT	a. Standards	(1) System cannot be used when needed without violating public law
	b. Procedures	(1) Equipment misused, fire not suppressed expediently
		(2) Equipment misused, fire not suppressed expediently
		(3) Equipment misused, fire not suppressed expediently
		(4) Equipment not usable
	c. Controls	(1) Equipment not usable
5. MISSION		(1) Fuel spills
		(2) Uncontrolled fire incident
		(3) Mission support requirements of MAFFE not thoroughly understood

Table 2. Hangar Protection Hazards — Installed Underwing System

CATEGORY	SUBCATEGORIES	HAZARDS/INSTALLED SYSTEM
1. MAN	a. Selection	(1) Incompetent; inadequate/unsuccessful training
		(2) Does not understand procedural guidance for activating/aborting the system
	b. Performance	(1) Improper maintenance/procedures
		(2) Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)
		(3) Unaware of priory placement of equipment
		(4) Perceives equipment as unnecessary, redundant, or inconvenient
		(5)
		(6) System struck by people performing other than mission activities (i.e.: sports, horseplay)
		(9) Person injured by discharge spray
	c. Personal Factors	(1) Delayed response
		(2) Lack of consistency in layout, setup, use
		(3) Using low level nozzles for convenience hooks
		(4) Intentional equipment activation/deactivation

Table 2. Hangar Protection Hazards — Installed Underwing System (Continued)

CATEGORY	SUBCATEGORIES	HAZARDS/INSTALLED SYSTEM
2. MEDIA	a. Climatic	(1)
		(2) System components freeze
		(3) Fluids freeze in system
		(4) Corrosion buildup causes equipment malfunction
		(5) Component or system failure
	b. Operational	(1) Maintenance person in aircraft when fire occurs
		(2) Delayed Fire Department response
		(3)
		(4) Foam pattern disrupted
		(5) System delayed or slow fire control
		(6) Person driven into fire by the force of the discharge
	c. Hygienic	(1) Hangar crowding
		(2) Conflicting maintenance operations
		(3) Blocked discharge
		(4)
	d. Vehicular/ Pedestrian	(1) Internal aircraft fires
		(2) Vehicular/AGE equipment fire
		(3) Fuel bowser located in hangar
		(4) Fires in adjacent support areas
3. MACHINE	a. Design	(1) Fuel ignites after draining into water drainage system
		(2)
		(3)
		(4) System activated/deactivated erroneously by surrounding activity
		(5)
		(6) Corrosion causes malfunction
		(8) Component fails or incorrect installations are completed
		(9) Environmental hazards require remediation after foam discharge

Table 2. Hangar Protection Hazards — Installed Underwing System (Continued)

CATEGORY	SUBCATEGORIES	HAZARDS/INSTALLED SYSTEM
3. MACHINE (Cont.)	b. Maintenance	(1) Equipment malfunctions (i.e. valves freeze)
		(2) System not maintained properly
		(5) Equipment malfunctions
		(8) Person experiences electrical shock during maintenance
	c. Technical Data	(1) Equipment malfunctions
		(2) Equipment malfunctions
		(3) Equipment not used correctly
		(4) Aircraft not appropriately protected
4. MANAGEMENT	a. Standards	(1)
	b. Procedures	(1) Equipment misused, fire not expediently suppressed
		(2) Equipment misused, fire not expediently suppressed
		(3) Equipment misused, fire not expediently suppressed
		(4) Equipment not usable
	c. Controls	(1)
5. MISSION OR MISHAP		(1) Fuel spills

STEP 1: IDENTIFY THE HAZARD

ACTION 3: LIST CAUSES

The risk analysis team identified causes for each hazard listed in Tables 1 and 2. Some hazards have multiple causes, as shown in Tables 3 and 4.

Table 3. Hangar Protection Hazards and Causes — MAFFE

			HAZARDS	CAUSES
1	a	(1)	Incompetent; inadequate or unsuccessful training	Individual lacks experience or understanding of task importance
		(2)	Does not understand procedural guidance for placement of MAFFE	Individual lacks experience or understanding of task procedures

Table 3. Hangar Protection Hazards and Causes — MAFFE (Continued)

			HAZARDS	CAUSES
1	b	(1)	Improper user maintenance/procedures	Ops Tempo excessive for maintenance personnel
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Person became excited due to emergency events
		(3)	Unaware of priority placement of equipment	Lack of experience and training
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	Lack of experience and training
		(5)	Workload negates importance of MAFFE handling	Lack of experience and training
		(6)	MAFFE struck by people performing other than mission activities (i.e.: sports, horseplay)	Carelessness
		(7)	Personnel fail to reposition MAFFE for short duration jobs	Lack of understanding of importance
		(8)	Inadequate foam concentration used during recharge	Interruption, accident, attention to detail
		(9)	Personnel injured by discharge spray	Person slips on floor after foam discharge
	c	(1)	Inadequate/inappropriate equipment use	Lack of motivation/poor attitude
		(2)	Lack of consistency in layout, setup, use	Maturity, sense of responsibility, experience
		(3)	Using MAFFE as a drying rack for personal rain gear	Perception of convenience vs. equipment importance
		(4)	Intentional equipment activation/deactivation	Bad attitude, hero syndrome
2	a	(1)	Temperature requires placement of fans that block appropriate MAFFE placement	Hot temperatures
		(2)	System components freeze	Doors left open during cold weather
		(3)	Fluids freeze in system	Extreme weather, heating system failure
		(4)	MAFFE battery charger vulnerable to climatic conditions	Battery charger vulnerable to climatic conditions
		(5)	Equipment components vulnerable to temperature extremes	Equipment components vulnerable to temperature extremes
	b	(1)	Maintenance person in aircraft when fire occurs	Aircraft design, performing required duties
		(2)	Delayed Fire Department response	False alarms, aircraft operations prevent hangar access, responding to previous IFE, alarm system failure

Table 3. Hangar Protection Hazards and Causes — MAFFE (Continued)

			HAZARDS	CAUSES
2	b	(3)	MAFFE creates obstruction to routine work procedures	Limited throw range
		(4)	Foam pattern disrupted	Routine work obstructs the MAFFE
		(5)	MAFFE unable to control fire	Fuel flows outside of the aircraft footprint
		(6)	Person driven into the fire by the force of the discharge	Person between nozzles and fire
		(7)	Person incurs back or foot injury when moving MAFFE	MAFFE designed to require movement; equipment is heavy and bulky to move
	c	(1)	Hangar crowding	Work surge or adverse weather conditions
		(2)	Conflicting maintenance operations	Work surge, ops tempo
		(3)	Blocked discharge	Discharge area marks require frequent repainting
		(4)	Unit improperly located	Location marks require frequent repainting
	d	(1)	Internal aircraft fires	Component failure, improper maintenance, accident, sabotage
		(2)	Vehicular/AGE equipment fire	Component failure, improper maintenance, accident, sabotage
		(3)	Fuel bowser located in hangar	Inappropriately located or not properly grounded
		(4)	Fires in adjacent support areas	Component failure, improper maintenance, accident, sabotage
3	a	(1)	Fuel ignites after draining into water drainage system	Lack of or inappropriate water drainage
		(2)	Inadequate foam coverage due to incorrect placement	Design requires precision placement for reliable performance
		(3)	Resources damaged by other activities or incorrect placement	MAFFE must be repositioned after each aircraft movement
		(4)	MAFFE activated/deactivated erroneously by surrounding activity	Surrounding equipment, location of switches, equipment markings, location of equipment
		(5)	Equipment requires visual observation to detect an inadvertent or erroneous shutdown	Visual observation and equipment reset doesn’t occur
		(6)	System components fail due to corrosion	System is subject to corrosion
		(7)	System does not provide alarm other than to the local area	Environmental sensors misread environmental clues
		(8)	Not applicable this system	N/A

Table 3. Hangar Protection Hazards and Causes — MAFFE (Continued)

			HAZARDS	CAUSES
3	a	(9)	Environmental hazards require remediation after foam discharge	Use of AFFF create environmental hazard
		(10)	Failure to control fire	Inadequate foam application rate
		(11)	Failure to control fire	Inadequate total foam quantity
		(12)	Failure to control fire	Inadequate foam discharge time
	b	(1)	Equipment malfunctions	Improper maintenance or grounding
		(2)	Hazardous waste, personnel injured	Safe storage and handling of batteries
		(3)	Personnel injured, equipment damaged	Use of floor jacks and stands with improper equipment or procedure
		(4)	Personnel injured	Use of nitrogen bottle lift with improper equipment or procedure
		(5)	Equipment malfunctions	Equipment subject to vector damage
		(6)	Aircraft struck by MAFFE during normal operations	MAFFE designed to require movement; equipment is heavy and bulky to move
		(7)	Personnel struck by MAFFE during normal operations	MAFFE designed to require movement; equipment is heavy and bulky to move
		(8)	Personnel experiences electrical shock during maintenance	Equipment requires maintenance which is inherently hazardous
	c	(1)	Equipment malfunctions	Inadequate technical data
		(2)	Equipment malfunctions	Users not following technical data
		(3)	Equipment not used correctly	Technical data not site specific (i.e. spotting plan not developed for specific hangar and specific assigned aircraft)
		(4)	Aircraft not appropriately protected	Spotting plan does not allow for other than currently assigned aircraft
4	a	(1)	System cannot be used when needed without violating public law	Equipment is currently configured so that initial implementation requires waiver to public law
	b	(1)	Equipment misused, fire not expediently suppressed	Failure to enforce standards
		(2)	Equipment misused, fire not expediently suppressed	Failure to provide appropriate training
		(3)	Equipment misused, fire not expediently suppressed	Failure to provide adequate supervision
		(4)	Equipment not usable	Management directs inappropriate allocation of equipment resources

Table 3. Hangar Protection Hazards and Causes — MAFFE (Continued)

			HAZARDS	CAUSES
5		(1)	Fuel spills	Human error, equipment failure
		(2)	Uncontrolled fire incident	Random coincidences
		(3)	Mission support requirements of MAFFE not thoroughly understood	Lack of management involvement

Table 4. Hangar Protection Hazards and Causes — Installed Underwing System

			HAZARDS	CAUSES
1	a	(1)	Incompetent; inadequate or unsuccessful training	Individual lacks experience or understanding of task importance
		(2)	Does not understand procedural guidance for activating/aborting the system	Individual lacks experience or understanding of task procedures
	b	(1)	Improper maintenance/procedures	Shortage of people and conflicting priorities
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Person became excited due to emergency events
		(3)	Unaware of priority placement of equipment	Lack of experience and training
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	Lack of experience and training
		(5)		
		(6)	System damage struck by people performing other than mission activities (i.e.: sports, horseplay)	Carelessness
		(7)		
		(9)	Person injured by discharge spray	Person slips on floor after foam discharge
	c	(1)	Delayed response	Lack of motivation/poor attitude
		(2)	Lack of consistency in layout, setup, use	Maturity, sense of responsibility, experience
		(3)	Using low level nozzles for convenience hooks	Perception of convenience vs. equipment importance
		(4)	Intentional equipment activation/deactivation	Bad attitude, hero syndrome
2	a	(1)		
		(2)	System components freeze	Doors left open due to cold weather
		(3)	Fluids freeze in system	Extreme weather, heating system failure
		(4)	Corrosion buildup causes equipment malfunction	System requires additional corrosion control for inferior quality water

Table 4. Hangar Protection Hazards and Causes — Installed Underwing System (Continued)

			HAZARDS	CAUSES
2	a	(5)	Component or system failure	Equipment components vulnerable to temperature extremes
	b	(1)	Maintenance person in aircraft when fire occurs	Aircraft design, performing required duties
		(2)	Delayed Fire Department response	False alarms, aircraft operations prevent hangar access, responding to previous IFE, alarm system failure
		(3)		
		(4)	Foam pattern disrupted	Routine work obstructs the installed system
		(5)	System delayed or slow fire control	Fuel flows outside of the foam delivery area
		(6)	Person driven into the fire by the force of the discharge	Person between nozzles and fire
	c	(1)	Hangar crowding	Work surge or adverse weather conditions
		(2)	Conflicting maintenance operations	Work surge, ops tempo
		(3)	Blocked discharge	Discharge area marks require frequent repainting
		(4)		
	d	(1)	Internal aircraft fires	Component failure, improper maintenance, accident, sabotage
		(2)	Vehicular/AGE equipment fire	Component failure, improper maintenance, accident, sabotage
		(3)	Fuel bowser located in hangar	Inappropriately located or not properly grounded
		(4)	Fires in adjacent support areas	Component failure, improper maintenance, accident, sabotage
3	a	(1)	Fuel ignites after draining into water drainage system	Lack of or inappropriate water drainage
		(2)		
		(3)		
		(4)	System activated/deactivated erroneously by surrounding activity	Surrounding equipment, location of switches, equipment markings, location of equipment
		(5)		
		(6)	Corrosion causes malfunction	System is subject to corrosion

Table 4. Hangar Protection Hazards and Causes — Installed Underwing System (Continued)

			HAZARDS	CAUSES
3	a	(7)	Inadvertent activation	Environmental sensors misread environmental clues
		(8)	Component fails or incorrect installations are completed	Monitoring or observation did not occur
		(9)	Environmental hazards require remediation after foam discharge	Use of AFFF creates environmental hazard
	b	(1)	Equipment malfunctions (i.e. valves freeze)	Improper maintenance or grounding
		(2)	System not maintained properly	Conflicting priorities, workload
		(5)	Equipment malfunctions	Equipment subject to vector damage
		(8)	Person experiences electrical shock during maintenance	Equipment requires maintenance which is inherently hazardous
	c	(1)	Equipment malfunctions	Inadequate technical data
		(2)	Equipment malfunctions	Users not following technical data
		(3)	Equipment not used correctly	Technical data not site specific
		(4)	Aircraft not appropriately protected	Spotting plan does not allow for other than currently assigned aircraft
4	a	(1)		
	b	(1)	Equipment misused, fire not expediently suppressed	Failure to enforce standards
		(2)	Equipment misused, fire not expediently suppressed	Failure to provide appropriate training
		(3)	Equipment misused, fire not expediently suppressed	Failure to provide adequate supervision
		(4)	Equipment not usable	Management directs shutdown to avoid false alarms directs system
5		(1)	Fuel spills	Human error, equipment failure

STEP 2: ASSESS THE RISK

ACTION 1: ASSESS HAZARD EXPOSURE

To complete this step, the risk analysis team considered each hazard identified in Step 1 and rated the hazard by level of exposure. Each hazard was evaluated against the following four criteria:

Time: How long a hazard is present compared to how long it is not present. A hazard may be present only a few minutes each time it occurs, or it may be continuing.

Proximity: Whether a hazard is near personnel or other valuable resources. A hazard may pose negligible threat to personnel, or it may be collocated with daily tasks.

Volume: How much of the hazard exists. A hazard may exist in low volume during some phases of work, or it may exist in high volume regardless of the workload.

Repetition: How often a hazard occurs. A hazard may occur infrequently, or it may be repeated at short intervals throughout a work process.

The team then assigned each hazard a rating of either “significant” (S) or “not significant” (-) for each of the four criteria. "Significant" ratings were assigned a value of 1; "not significant" ratings were assigned a value of 0. Points were totaled for each hazard. The team used these ratings as a systematic method of assigning probability to evaluate risk. Results are shown in Tables 5 and 6.

Table 5. Hangar Protection Hazard Exposure — MAFFE

			HAZARDS	TIME	PROXIMITY	VOLUME	REPETITION	TALLY
1	a	(1)	Incompetent; inadequate or unsuccessful training	-	-	-	-	0
		(2)	Does not understand procedural guidance for placement of MAFFE	S	S	S	S	4
	b	(1)	Improper user maintenance/procedures	S	S	-	S	3
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	S	S	S	S	4
		(3)	Unaware of priority placement of equipment	S	S	S	S	4
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	S	S	-	-	2
		(5)	Workload negates importance of MAFFE handling	S	S	S	S	4
		(6)	MAFFE struck by people performing other than mission activities (i.e.: sports, horseplay)	-	S	-	-	1
		(7)	Personnel fail to reposition MAFFE for short duration jobs	-	S	S	S	3
		(8)	Inadequate foam concentration used during recharge	-	S	-	-	1
		(9)	Person injured by discharge spray	-	S	S	-	2
	c	(1)	Inadequate/inappropriate equipment use	-	S	-	-	1
		(2)	Lack of consistency in layout, setup, use	S	S	S	S	4
		(3)	Using MAFFE as a drying rack for personal rain gear	-	S	-	S	2
		(4)	Intentional equipment activation/deactivation	-	S	-	-	1
2	a	(1)	Fans block appropriate MAFFE placement	-	S	-	-	1
		(2)	System components freeze	-	S	-	-	1
		(3)	Fluids freeze in system	-	S	-	-	1

Table 5. Hangar Protection Hazard Exposure — MAFFE (Continued)

			HAZARDS	TIME	PROXIMITY	VOLUME	REPETITION	TALLY
2	a	(4)	Battery charger fails	-	S	-	-	1
		(5)	Component or system failure	-	S	-	-	1
	b	(1)	Maintenance person in aircraft when fire occurs	S	S	S	S	4
		(2)	Delayed Fire Department response	-	S	S	-	2
		(3)	MAFFE creates obstruction to routine work procedures	S	S	S	S	4
		(4)	Foam pattern disrupted	S	S	S	S	4
		(5)	MAFFE unable to control fire	-	S	S	S	3
		(6)	Person driven into the fire by the force of the discharge	-	S	-	-	1
		(7)	Person incurs back or foot injury when moving MAFFE	S	S	S	S	4
	c	(1)	Hangar crowding	S	S	S	S	4
		(2)	Conflicting maintenance operations	S	S	S	S	4
		(3)	Blocked discharge	S	S	S	S	4
		(4)	Equipment positioned incorrectly	-	S	S	-	2
	d	(1)	Internal aircraft fires	S	S	S	S	4
		(2)	Vehicular/AGE equipment fire	S	S	S	S	4
		(3)	Fuel bowser located in hangar	S	S	S	-	3
		(4)	Fires in adjacent support areas	S	S	S	S	4
3	a	(1)	Fuel ignites after draining into water drainage system	-	S	S	-	2
		(2)	Inadequate foam coverage due to incorrect placement	S	S	S	S	4
		(3)	Resources damaged by other activities or incorrect placement	S	S	S	S	4
		(4)	MAFFE activated/deactivated erroneously by surrounding activity	S	S	S	-	3
		(5)	Inadvertent or erroneous shutdown	S	S	S	S	4
		(6)	Corrosion causes malfunction	S	S	-	-	2
		(7)	Inadvertent activation	S	S	S	-	3
		(8)	N/A	-	-	-	-	0
		(9)	Environmental hazards require remediation after foam discharge	S	S	-	S	3
		(10)	Failure to control fire	S	S	S	S	4

Table 5. Hangar Protection Hazard Exposure — MAFFE (Continued)

			HAZARDS	TIME	PROXIMITY	VOLUME	REPETITION	TALLY
3	a	(11)	Failure to control fire.	S	S	S	S	4
		(12)	Failure to control fire.	S	S	S	S	4
	b	(1)	Equipment malfunctions	-	S	S	-	2
		(2)	Hazardous waste, personnel injured	S	S	-	-	2
		(3)	Personnel injured, equipment damaged	-	S	-	-	1
		(4)	Personnel injured, equipment damaged	-	S	-	-	1
		(5)	Equipment malfunctions (vectors)	-	-	-	-	0
		(6)	Aircraft struck by MAFFE during normal operations	S	S	S	S	4
		(7)	Person struck by MAFFE during normal operations	S	S	S	S	4
		(8)	Person experiences electrical shock during maintenance	-	S	-	S	2
	c	(1)	Equipment malfunctions (inadequate tech data)	-	S	S	-	2
		(2)	Equipment malfunctions (user not following tech data)	-	S	S	-	2
		(3)	Equipment not used correctly	S	S	-	-	2
		(4)	Aircraft not appropriately protected	-	S	-	-	1
4	a	(1)	System cannot be used when needed without violating public law	S	S	S	-	3
	b	(1)	Equipment misused, fire not expediently suppressed	-	S	S	S	3
		(2)	Equipment misused, fire not expediently suppressed	S	S	-	-	2
		(3)	Equipment misused, fire not expediently suppressed	S	S	-	-	2
		(4)	Equipment not usable	S	S	-	-	2
	c	(1)	Equipment not usable	S	S	-	-	2
5	a	(1)	Fuel spills	S	S	S	S	4
		(2)	Uncontrolled fire incident	S	S	-	-	2
		(3)	Mission support requirements of MAFFE not thoroughly understood	-	S		-	2

Table 6. Hangar Protection Hazard Exposure — Installed Underwing System

			HAZARDS	TIME	PROXIMITY	VOLUME	REPETITION	TALLY
1	a	(1)	Incompetent; inadequate or unsuccessful training	S	S	-	-	2
		(2)	Does not understand procedural guidance for activating/aborting the system	S	S	-	-	2
	b	(1)	Improper maintenance/procedures	S	S	-	S	3
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	S	S	S	S	4
		(3)	Unaware of priority placement of equipment	S	S	S	S	4
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	S	S	-	-	2
		(6)	System struck by people performing other than mission activities (i.e.: sports, horseplay)	-	S	-	-	1
		(9)	Person injured by discharge spray	-	S	S	-	2
	c	(1)	Delayed response	S	S	S	-	3
		(2)	Lack of consistency in layout, setup, use	S	S	-	-	2
		(3)	Using low level nozzles for convenience hooks	-	S	-	-	1
		(4)	Intentional equipment activation/deactivation	-	S	-	-	1
2	a	(2)	System components freeze	-	S	-	-	1
		(3)	Fluids freeze in system	-	S	-	-	1
		(4)	Corrosion build up causes equipment malfunction	-	S	S	-	2
		(5)	Component or system failure	-	S	-	-	1
	b	(1)	Maintenance person in aircraft when fire occurs	S	S	S	S	4
		(2)	Delayed Fire Department response	-	S	S	-	2
		(4)	Foam pattern disrupted	S	S	S	S	4
		(5)	System delayed or slow fire control	S	S	S	S	4
		(6)	Person driven into fire by the force of the discharge	-	S	-	-	1
	c	(1)	Hangar crowding	S	S	S	S	4
		(2)	Conflicting maintenance operations	S	S	S	S	4

Table 6. Hangar Protection Hazard Exposure — Installed Underwing System (Continued)

			HAZARDS	TIME	PROXIMITY	VOLUME	REPETITION	TALLY
2	c	(3)	Blocked discharge	-	S	S	S	3
	d	(1)	Internal aircraft fires	S	S	S	S	4
		(2)	Vehicular/AGE equipment fire	S	S	S	S	4
		(3)	Fuel bowser located in hangar	S	S	S	-	3
		(4)	Fires in adjacent support areas	S	S	S	S	4
3	a	(1)	Fuel ignites after draining into water drainage system	-	S	S	-	2
		(4)	System activated/deactivated erroneously by surrounding activity	S	S	S	-	3
		(6)	Corrosion causes malfunction	S	S	-	-	2
		(7)	Inadvertent activation	S	S	S	-	3
		(8)	Component fails or incorrect installations are completed	S	S	S	S	4
		(9)	Environmental hazards require remediation after foam discharge	S	S	S	S	4
	b	(1)	Equipment malfunctions (i.e. valves freeze)	-	S	S	-	2
		(2)	System not maintained properly	S	S	S	S	4
		(5)	Equipment malfunctions	S	S	-	S	3
		(8)	Person experiences electrical shock during maintenance	S	S	-	S	3
	c	(1)	Equipment malfunctions	-	S	S	S	3
		(2)	Equipment malfunctions	-	S	S	-	2
		(3)	Equipment not used correctly	S	S	-	-	2
		(4)	Aircraft not appropriately protected	-	S	-	-	1
4	b	(1)	Equipment misused, fire not expediently suppressed	-	S	S	S	3
		(2)	Equipment misused, fire not expediently suppressed	S	S	-	-	2
		(3)	Equipment misused, fire not expediently suppressed	S	S	-	-	2
		(4)	Equipment not usable	S	S	-	S	3
5		(1)	Fuel spills	S	S	S	S	4

STEP 2: ASSESS THE RISK

ACTION 2: ASSESS HAZARD SEVERITY

After assessing hazard exposure, the risk analysis team applied the categories shown in Table 7 to assess the severity of each hazard.

Table 7. Hazard Severity Categories

CATEGORY	IMPACT ON RESOURCES
CATASTROPHIC - I	Complete mission failure, death, or loss of system
CRITICAL – II	Major mission degradation, severe injury, occupational illness or major system damage
MODERATE – III	Minor mission degradation, injury, minor occupational illness, or minor system damage
NEGLIGIBLE – IV	Less than minor mission degradation, injury, occupational illness, or minor system damage

The potential impact on resources was based upon worst possible outcome, as recommended in AFPAM 91-215. Assigned severities are shown in Tables 8 and 9.

STEP 2: ASSESS THE RISK

ACTION 3: ASSESS MISHAP PROBABILITY

The team assigned qualitative mishap probabilities to each hazard as defined in AFPAM 91-215. The assessment was based upon research and analysis of historical data from similar missions and systems. Probabilities are shown in Table 8. Probabilities derived during this step are also displayed in Tables 9 and 10.

Table 8. Probability Categories

CATEGORY	PROJECTED OCCURRENCE
FREQUENT - A	Will occur almost every time the system is operated
LIKELY - B	Will occur but not every time the system is operated
OCCASIONAL - C	Can occur but not often over the operational period
SELDOM - D	Can occur but not likely over the operational period
UNLIKELY -E	Remotely possible to occur over the operational period

Table 9. Hangar Protection Hazard Probability, Severity, and Risk Index — MAFFE

			HAZARDS	SEVERITY	PROBABILITY	S	P	RAI
1	a	(1)	Incompetent; inadequate or unsuccessful training	Critical	Seldom	II	D	Medium
		(2)	Does not understand procedural guidance for placement of MAFFE	Critical	Occasional	II	C	High
	b	(1)	Improper user maintenance/procedures	Moderate	Likely	III	B	Medium
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Critical	Occasional	II	C	High
		(3)	Unaware of priority placement of equipment	Moderate	Occasional	III	C	Medium
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	Moderate	Occasional	III	C	Medium
		(5)	Workload negates importance of MAFFE handling	Critical	Occasional	II	C	High
		(6)	MAFFE struck by people performing other than mission activities (i.e.: sports, horseplay)	Moderate	Likely	III	B	Medium
		(7)	Personnel fail to reposition MAFFE for short duration jobs	Critical	Likely	II	B	High
		(8)	Inadequate foam concentration used during recharge	Critical	Unlikely	II	E	Low
		(9)	Person injured by discharge spray	Moderate	Likely	III	B	Medium
	c	(1)	Inadequate/inappropriate equipment use	Moderate	Occasional	III	C	Medium
		(2)	Lack of consistency in layout, setup, use	Moderate	Occasional	III	C	Medium
		(3)	Using MAFFE as a drying rack for personal rain gear	Critical	Seldom	II	D	Medium
		(4)	Intentional equipment activation/deactivation	Catastrophic	Unlikely	I	E	Medium
2	a	(1)	Fans block appropriate MAFFE placement	Catastrophic	Unlikely	I	E	Medium
		(2)	System components freeze	Catastrophic	Unlikely	I	E	Medium
		(3)	Fluids freeze in system	Catastrophic	Unlikely	I	E	Medium
		(4)	Battery charger fails	Negligible	Occasional	IV	C	Low
		(5)	Component or system failure	Catastrophic	Unlikely	I	E	Medium

Table 9. Hangar Protection Hazard Probability, Severity, and Risk Index — MAFFE (Continued)

			HAZARDS	SEVERITY	PROBABILITY	S	P	RAI
2	b	(1)	Maintenance person in aircraft when fire occurs	Catastrophic	Seldom	I	D	High
		(2)	Delayed Fire Department response	Catastrophic	Unlikely	I	E	Medium
		(3)	MAFFE creates obstruction to routine work procedures	Negligible	Frequent	IV	A	Medium
		(4)	Foam pattern disrupted	Catastrophic	Frequent	I	A	Extreme
		(5)	MAFFE unable to control fire	Catastrophic	Occasional	I	C	High
		(6)	Person driven into the fire by the force of the discharge	Catastrophic	Unlikely	I	E	Medium
		(7)	Person incurs back or foot injury when moving MAFFE	Moderate	Occasional	III	C	Medium
	c	(1)	Hangar crowding	Catastrophic	Seldom	I	D	High
		(2)	Conflicting maintenance operations	Critical	Likely	II	B	High
		(3)	Blocked discharge	Catastrophic	Unlikely	I	E	Medium
		(4)	Equipment positioned incorrectly	Catastrophic	Unlikely	I	E	Medium
	d	(1)	Internal aircraft fires	Catastrophic	Occasional	I	C	High
		(2)	Vehicular/AGE equipment fire	Moderate	Occasional	III	C	Medium
		(3)	Fuel bowser located in hangar	Moderate	Occasional	III	C	Medium
		(4)	Fires in adjacent support areas	Negligible	Occasional	IV	C	Low
3	a	(1)	Fuel ignites after draining into water drainage system	Moderate	Seldom	III	D	Low
		(2)	Inadequate foam coverage due to incorrect placement	Catastrophic	Frequent	I	A	Extreme
		(3)	Resources damaged by other activities or incorrect placement	Negligible	Occasional	IV	C	Low
		(4)	MAFFE activated/deactivated erroneously by surrounding activity	Catastrophic	Seldom	I	D	High
		(5)	Inadvertent or erroneous shutdown	Catastrophic	Occasional	I	C	High
		(6)	Corrosion causes malfunction	Critical	Seldom	II	D	Medium
		(7)	Inadvertent activation	Negligible	Occasional	IV	C	Low
		(8)	N/A					
		(9)	Environmental hazards require remediation after foam discharge	Moderate	Occasional	III	C	Medium
		(10)	Failure to control fire	Catastrophic	Likely	I	B	Extreme
		(11)	Failure to control fire	Catastrophic	Occasional	I	C	High
		(12)	Failure to control fire	Catastrophic	Occasional	I	C	High

Table 9. Hangar Protection Hazard Probability, Severity, and Risk Index — MAFFE (Continued)

			HAZARDS	SEVERITY	PROBABILITY	S	P	RAI
3	b	(1)	Equipment malfunctions	Moderate	Seldom	III	D	Low
		(2)	Hazardous waste, personnel injured	Critical	Unlikely	II	E	Low
		(3)	Personnel injured, equipment damaged	Critical	Unlikely	II	E	Low
		(4)	Personnel injured, equipment damaged	Moderate	Occasional	III	C	Medium
		(5)	Equipment malfunctions (vectors)	Moderate	Seldom	III	D	Low
		(6)	Aircraft struck by MAFFE during normal operations	Moderate	Unlikely	III	E	Low
		(7)	Person struck by MAFFE during normal operations	Moderate	Seldom	III	D	Low
		(8)	Person experiences electrical shock during maintenance	Moderate	Seldom	III	D	Low
	c	(1)	Equipment malfunctions (inadequate tech data)	Critical	Seldom	II	D	Medium
		(2)	Equipment malfunctions (user not following tech data)	Critical	Seldom	II	D	Medium
		(3)	Equipment not used correctly	Catastrophic	Unlikely	I	E	Medium
		(4)	Aircraft not appropriately protected	Catastrophic	Seldom	I	D	High
4	a	(1)	System cannot be used when needed without violating public law	Catastrophic	Occasional	I	C	High
	b	(1)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(2)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(3)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(4)	Equipment not usable	Catastrophic	Unlikely	I	E	Medium
	c	(1)	Equipment not usable	Catastrophic	Unlikely	I	E	Medium
5	a	(1)	Fuel spills	Moderate	Frequent	III	A	High
		(2)	Uncontrolled fire incident	Catastrophic	Unlikely	I	E	Medium
		(3)	Mission support requirements of MAFFE not thoroughly understood	Critical	Seldom	II	D	Medium

Table 10. Hangar Protection Hazard Probability, Severity, and Risk Index — Installed Underwing System

			HAZARDS	SEVERITY	PROBABILITY	S	P	RAI
1	a	(1)	Incompetent; inadequate or unsuccessful training	Critical	Seldom	II	D	Medium
		(2)	Does not understand procedural guidance for activating/aborting the system	Critical	Seldom	II	D	Medium
	b	(1)	Improper user maintenance/procedures	Moderate	Likely	III	B	Medium
		(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Moderate	Occasional	III	C	Medium
		(3)	Unaware of priority placement of equipment	Moderate	Occasional	III	C	Medium
		(4)	Perceives equipment as unnecessary, redundant, or inconvenient	Moderate	Occasional	III	C	Medium
		(6)	System struck by people performing other than mission activities (i.e.: sports, horseplay)	Moderate	Occasional	III	C	Medium
		(9)	Person injured by discharge spray	Moderate	Likely	III	B	Medium
	c	(1)	Delayed response	Moderate	Seldom	III	D	Low
		(2)	Lack of consistency in layout, setup, use	Moderate	Unlikely	III	E	Low
		(3)	Using low level nozzles for convenience hooks	Critical	Seldom	II	D	Medium
		(4)	Intentional equipment activation/deactivation	Catastrophic	Unlikely	I	E	Medium
2	a	(2)	System components freeze	Catastrophic	Seldom	I	D	High
		(3)	Fluids freeze in system	Catastrophic	Unlikely	I	E	Medium
		(4)	Corrosion build up causes equipment malfunction	Catastrophic	Unlikely	I	E	Medium
		(5)	Component or system failure	Catastrophic	Unlikely	I	E	Medium
	b	(1)	Maintenance person in aircraft when fire occurs	Catastrophic	Seldom	I	D	High
		(2)	Delayed Fire Department response	Catastrophic	Unlikely	I	E	Medium
		(4)	Foam pattern disrupted	Critical	Frequent	II	A	Extreme
		(5)	System delayed or slow fire control	Moderate	Likely	III	B	Medium
		(6)	Person driven into the fire by the force of the discharge	Catastrophic	Unlikely	I	E	Medium

Table 10. Hangar Protection Hazard Probability, Severity, and Risk Index — Installed Underwing System (Continued)

			HAZARDS	SEVERITY	PROBABILITY	S	P	RAI
2	c	(1)	Hangar crowding	Catastrophic	Seldom	I	D	High
		(2)	Conflicting maintenance operations	Critical	Likely	II	B	High
		(3)	Blocked discharge	Catastrophic	Unlikely	I	E	Medium
	d	(1)	Internal aircraft fires	Catastrophic	Occasional	I	C	High
		(2)	Vehicular/AGE equipment fire	Moderate	Occasional	III	C	Medium
		(3)	Fuel bowser located in hangar	Moderate	Occasional	III	C	Medium
		(4)	Fires in adjacent support areas	Negligible	Occasional	IV	C	Low
3	a	(1)	Fuel ignites after draining into water drainage system	Moderate	Seldom	III	D	Low
		(4)	System activated/deactivated erroneously by surrounding activity	Catastrophic	Unlikely	I	E	Medium
		(6)	Corrosion causes malfunction	Catastrophic	Unlikely	I	E	Medium
		(7)	Inadvertent activation	Negligible	Occasional	IV	C	Low
		(8)	Component fails or incorrect installations are completed	Catastrophic	Occasional	I	C	High
		(9)	Environmental hazards require remediation after foam discharge	Moderate	Occasional	III	C	Medium
	b	(1)	Equipment malfunctions	Moderate	Occasional	III	C	Low
		(2)	System not maintained properly	Critical	Likely	II	B	High
		(5)	Equipment malfunctions	Moderate	Seldom	III	D	Low
		(8)	Person experiences electrical shock during maintenance	Moderate	Seldom	III	D	Low
	c	(1)	Equipment malfunctions	Catastrophic	Occasional	I	C	High
		(2)	Equipment malfunctions	Critical	Seldom	II	D	Medium
		(3)	Equipment not used correctly	Critical	Unlikely	II	E	Low
		(4)	Aircraft not appropriately protected	Moderate	Seldom	III	D	Low
4	b	(1)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(2)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(3)	Equipment misused, fire not expediently suppressed	Critical	Seldom	II	D	Medium
		(4)	Equipment not usable	Catastrophic	Seldom	I	D	High
5	a	(1)	Fuel spills	Negligible	Frequent	IV	A	Medium

STEP 2: ASSESS THE RISK

ACTION 4: COMPLETE RISK ASSESSMENT

The risk analysis team combined the Severity (Step 2, Action 2) and Probability (Step 2, Action 3) estimates to create a matrix defining a risk assessment index (RAI). RAIs derived during this step are displayed in Tables 9 and 10. Using these RAIs, Tables 11 and 12 were prepared to illustrate the combined Severity/Probability profile and associated risk classification for each hazard. The team used this information to determine which risks were acceptable and how to allocate resources. Only hazards rated "Extreme" or “High” were assessed further. Medium, low and negligible risks were omitted from further analysis.

Table 11. Combined Severity/Probability Profile and Risk Index — MAFFE

		PROBABILITY				
		FREQUENT	LIKELY	OCCASIONAL	SELDOM	UNLIKELY
SEVERITY		**A**	**B**	**C**	**D**	**E**
Catastrophic	I	Extreme 2b(4) 3a(2)	Extreme 3a(10)	High 2b(5) 2d(1) 3a(5) 4a(1) 3a(11) 3a(12)	High 2b(1) 2c(1) 3a(4) 3c(4)	Medium 1c(4) 2a(1) 2a(2) 2a(3) 2a(5) 2b(6) 2c(3) 2c(4) 3c(3) 4b(4) 4c(1) 5a(2)
Critical	II	Extreme	High 1b(7) 2c(2)	High 1a(2) 1b(2) 1b(5)	Medium 1a(1) 1c(3) 3a(6) 3c(1) 3c(2) 4b(1) 4b(2) 4b(3) 5a(3)	Low 1b(8) 3b(2) 3b(3)
Moderate	III	High 5a(1)	Medium 1b(1) 1b(6) 1b(9)	Medium 1b(3) 1b(4) 1c(2) 2d(2) 2d(3) 2d(4) 2b(7) 3a(9) 3b(4)	Low 3a(1) 3b(5) 3b(7) 3b(8)	Low 3b(6)
Negligible	IV	Medium 2b(3)	Low	Low 2a(4) 3a(3) 3a(7)	Low	Low

Table 12. Combined Severity/Probability Profile and Risk Index — Installed Underwing System

SEVERITY		PROBABILITY				
		FREQUENT	LIKELY	OCCASIONAL	SELDOM	UNLIKELY
		A	B	C	D	E
Catastrophic	I	Extreme	Extreme	High 2d(1) 3a(8) 3c(1)	High 2a(2) 2b(1) 2c(1) 4b(4)	Medium 1c(4) 2a(3) 2a(4) 2a(5) 2b(2) 2b(6) 2c(3) 3a(4) 3a(6)
Critical	II	Extreme 2b(4)	High 2c(2) 3b(2)	High	Medium 1a(1) 1a(2) 1c(3) 3c(2) 4b(1) 4b(2) 4b(3)	Low 3c(3)
Moderate	III	High	Medium 1b(1) 1b(9) 2b(5)	Medium 1b(2) 1b(3) 1b(4) 1b(6) 2d(2) 2d(3) 3a(9) 3b(1)	Low 1c(1) 3a(1) 3b(5) 3b(8) 3c(4)	Low 1c(2)
Negligible	IV	Medium 5a(1)	Low	Low 2d(4) 3a(7)	Low	Low

STEP 3: ANALYZE RISK CONTROL MEASURES

ACTION 1: IDENTIFY CONTROL OPTIONS

Step 3 targets the highest priority risk issues for control — hazards rated "Extreme" or "High" in Step 2, Action 4 and selected for further analysis. Possible causes listed in Step 1, Action 3 were reexamined to generate ideas for controls. The team analyzed each hazard to determine which control measures could be applied (Tables 13 and 14).

Table 13. Fire Risk Control Options — MAFFE

			HAZARDS/MAFFE	CONTROL OPTIONS
1	a	(2)	Does not understand procedural guidance for placement of MAFFE	Use currently designed and available installed system instead of the MAFFE
				Require the manufacturer provide more specific procedural guidance and training checklists. Use guidance and checklists to provide training.
1	b	(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Use ancillary automatic warning devices.
				Provide training and practice on use of the MAFFE
1	b	(5)	Workload negates importance of MAFFE handling	Provide training and practice on use of the MAFFE
				Hire more people or reduce workload
1	b	(7)	Personnel fail to reposition MAFFE for short duration jobs	Provide training and practice on use of the MAFFE
				Limit maintenance to procedures that aren't inherently hazardous unless MAFFE is in place
2	b	(1)	Maintenance person in aircraft when hangar fire occurs	Defuel the aircraft before towing it into the hangar
				Delox the aircraft before towing it into the hangar
				Defuel and delox the aircraft before towing it into the hangar
2	b	(4)	Foam pattern disrupted	Provide physical barriers to restrict obstructions
				Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)
				Mark floor to show areas available for maintenance portable equipment positioning
				Provide training on procedures for correct support equipment placement

Table 13. Fire Risk Control Options — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS
2	b	(5)	MAFFE unable to control fire	Defuel the aircraft before towing it into the hangar
				Use more units
2	c	(1)	Hangar crowding	Delay maintenance
				Build more hangars
2	c	(2)	Conflicting maintenance operations	Limit number of aircraft in hangar
				Provide training and practice on use of the MAFFE
2	d	(1)	Internal aircraft fires	Post guards to avoid sabotage
				Require person to be present whenever power is applied to the aircraft
				Increase preventive maintenance on high failure parts
				Provide training and practice on use of the MAFFE
				Enforce correct maintenance procedures
3	a	(2)	Inadequate foam coverage due to incorrect placement	Use more units
				Increase training on procedures
				Use equipment which does not require movement
3	a	(4)	MAFFE activated/deactivated erroneously by surrounding activity	Use equipment with more effective switch protection
				Provide an expanded clear zone around the MAFFE
				Check system more frequently
3	a	(5)	Inadvertent or erroneous shutdown	Use equipment with more effective switch protection
				Use equipment which provides power loss alarms or shutoff alarms
				Check system more frequently
3	a	(10)	Failure to control fire	Use more MAFFE units
3	a	(11)	Failure to control fire	Use more MAFFE units
3	a	(12)	Failure to control fire	Reduce fire department response time
3	c	(4)	Aircraft not appropriately protected	Delay maintenance until spotting plan developed
4	a	(1)	System cannot be used when needed without violating public law	Obtain appropriate approvals. Submit notification to Congress prior to implementing the system AF-wide

Table 13. Fire Risk Control Options — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS
5	a	(1)	Fuel spills	Restrict use of fuel in all hangar operations
				Use safety or warning devices to reduce the risk
				Use fuels only outdoors. Bring only unfueled aircraft into hangars
				Obtain commercial insurance for fires due to fuel spills

Table 14. Fire Risk Control Options — Installed Underwing System

				CONTROL CATEGORY				
			HAZARDS	A	R	S	T	CONTROL OPTIONS
2	a	(2)	System components freeze		X			Provide temperature warning per current criteria
2	b	(1)	Maintenance person in aircraft when fire occurs		X			Defuel the aircraft before towing it into the hangar
					X			Delox the aircraft before towing it into the hangar
					X			Defuel and delox the aircraft before towing it into the hangar
2	b	(4)	Foam pattern disrupted		X			Install additional nozzles to support enhanced system performance
					X			Provide physical barriers to restrict obstructions
					X			Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)
					X			Mark floor to show areas available for maintenance portable equipment positioning
					X			Provide training on procedures for correct support equipment placement
					X			Add mobile systems to enhance coverage
2	c	(1)	Hangar crowding	X				Delay maintenance
							X	Build more hangars
2	c	(2)	Conflicting maintenance operations			X		Limit number of aircraft in hangar
					X			Provide training and practice on use of the system

Table 14. Fire Risk Control Options — Installed Underwing System (Continued)

			HAZARDS	CONTROL CATEGORY A	R	S	T	CONTROL OPTIONS
2	d	(1)	Internal aircraft fires		X			Post guards to avoid sabotage
						X		Increase preventive maintenance on high failure parts
					X			Require person to be present whenever power is applied to the aircraft
3	a	(8)	Component fails or incorrect installations are completed			X		Increase frequency of maintenance or test procedures
					X			Provide training and practice on use of the system
					X			Use equipment with more effective switch protection
					X			Use equipment which provides power loss alarms or shutoff alarms
					X			Check system more frequently
3	b	(2)	System not maintained properly			X		Complete all appropriate maintenance on schedule
					X			Stress the priority of maintenance (maintenance is of equal importance of the equipment it protects)
					X			Provide training and practice on use of the system
					X			Provide technical orders to support the system
3	c	(1)	Equipment malfunctions (inadequate tech data)		X			Require appropriate, comprehensive technical data be provided with each system
4	b	(4)	Equipment not usable		X			Require MAJCOM notification of system shutdowns
				X				Delay, postpone, or cancel maintenance until the system is repaired
					X			Institute a fire watch schedule

Rationale for Selection of Reduction Control Option

Avoidance:
Avoiding risk would require fundamental changes in the systems design (i.e., MAFFE or Installed Underwing System) aircraft maintenance procedures, such as mandatory defueling prior to every maintenance action in a hangar.

<u>Reduction</u>:
When addressing each of the risk reduction methods, a systematic approach is taken to the actions possible, in priority order. The overall goal of risk management is to plan missions or design the risk out of a system; it is least desirable to provide procedures or training to control risks. Elimination of all hazards is not practicable because the nature of aircraft hangar operations makes hazard-free design impossible or impractical. A proven order of precedence for managing hazards and reducing risk is:

1. **Plan or design for minimum risk.**
   From the first, plan the mission or design the system to mitigate the hazards.
2. **Incorporate safety devices.**
   If identified hazards cannot be eliminated or their associated risk adequately reduced by modifying the mission or system risk should be reduced to an acceptable level through the use of safety design features or devices.
3. **Provide warning devices.**
   When mission planning, system design, and safety devices cannot effectively eliminate identified hazards or adequately reduce associated risk, warning devices should be used to detect the condition and alert personnel of the hazard. However, warning devices by themselves may not be effective without training or procedures for response to hazardous conditions.
4. **Develop written cautions, warnings, procedures and training.**
   Where it is impractical to eliminate hazards through design or adequately reduce the associated risk with safety and warning devices, written cautions, warnings, procedures and training should be used. In accordance with the guidance contained in MIL-STD-882C, written changes (e.g., cautions, warnings, procedures, and training) will not be used as the only risk reduction methods for Category I or II hazards. No reduction in the hazards results in those situations where only these written changes are identified for Category I and II hazards.

<u>Spreading</u>:
Spreading risk would require fundamental changes in aircraft maintenance procedures, such as some maintenance being conducted only outside the hangar. Impact on current aircraft procedures is an unacceptable method of reducing hazard levels.

<u>Transferring</u>:
Privatization of aircraft hangars or transferring aircraft maintenance to private industry is a possible alternative, but were not considered to be within the scope of this risk analysis.

Features/Functions of Fire Suppression Systems

<u>Fire Suppression</u>. Suppression involves sharply reducing the heat release rate of a fire and preventing its re-growth by means of direct and sufficient application of water (or other agent) through the fire plume to the burning fuel surface (National Fire Protection Association (NFPA) 13, *1996 Edition Standard for the Installation of Sprinkler Systems,* paragraph 1-4.2). In aircraft hangars, a suppression system is an integrated system which:

- Detects the presence of a fire.
- Activates evacuation signals in the building.
- Activates release of a fire suppression agent.
- Transmits signals to a monitoring station (normally the Fire Department).

Current Standards and Guidance

ETL 98-7, *Fire Protection Engineering Criteria – New Aircraft Facilities*. This ETL provides fire protection criteria for facilities housing Air Force aircraft or other aircraft on Air Force installations. It applies to all types of aircraft facilities, including (but not limited to) maintenance, servicing, and storage hangars; corrosion control hangars; fuel cell repair hangars; depot overhaul facilities; research and development (R&D)/testing facilities housing aircraft; and all types of aircraft shelters (weather, alert, semi-hardened and hardened). This ETL is the Air Force alternative to NFPA 409, *1995 Edition Standard on Aircraft Hangars*, and is used instead of that standard except as noted in the ETL.

ETL 98-8, *Fire Protection Engineering Criteria – Existing Aircraft Facilities*. This ETL provides fire protection criteria for existing facilities housing Air Force aircraft or other aircraft on Air Force installations. It applies to all types of existing aircraft facilities with currently installed fire suppression systems, including (but not limited to) maintenance, servicing, and storage hangars; corrosion control hangars; fuel cell repair hangars; depot overhaul facilities; research and development (R&D)/testing facilities housing aircraft; and all types of aircraft shelters (weather, alert, semi-hardened and hardened). This ETL is the Air Force alternative to NFPA 409, *1995 Edition Standard on Aircraft Hangars*, and is used instead of that standard except as noted in the ETL.

MIL-HDBK-1008C, *Fire Protection Engineering Criteria for Facility Design, Engineering, and Construction*. This handbook provides the fundamental fire engineering requirement for DOD facilities, defines the applicable baseline consensus standards, and provides the technical authority for alternative methods, when appropriate. It provides detailed guidance for the incorporation of fire protection engineering in design and construction of DOD facilities. Concerns for property, equipment, and personnel are among the comprehensive considerations to ensure safety of human life, continuity of mission, and minimize damage to property and equipment. The handbook was developed jointly by the Naval Facilities Engineering Command, Army Corps of Engineers, Air Force Civil Engineering, Deputy Chief of Staff for Installations and Logistics of the Marine Corps, other Government agencies (such as the Defense Logistics Agency), and the private sector. Section 4.16 of the handbook provides requirements for aircraft hangars that are used to supplement NFPA 409.

STEP 3: ANALYZE CONTROL MEASURES

ACTION 2: DETERMINE CONTROL EFFECTS

Impact on Hazard Severity

The team considered a number of scenarios (summarized in Table 15) to evaluate the effects on hazard severity of the two system options under consideration. The system options were judged based on the basic design characteristics/limitations of both systems, laboratory and full-scale fire testing, and the Hughes Associates report of October 1998, "Test of Alternative Fire Protection Methods for Air Force Hangars." Results and engineering recommendations provided by Hughes Associates based on the testing included:

- Compressed air delivery of AFFF solution neither improves nor diminishes the fire fighting performance of AFFF.
- Aircraft within 65 feet of even a small JP-8 fuel fire are subject to structural damage regardless of the aircraft material.
- Mobile automatic foam fire extinguishers (of the type and performance tested) cannot be used in lieu of currently accepted low level foam delivery systems.
- Water suppression systems alone will not prevent growth of a JP-8 spill fire.

Table 15. Hangar Fire Suppression Control Method Event Scenarios

SCENARIO	MAFFE	INSTALLED UNDERWING
System fails	Fire Department responds in 3-5 minutes. High fire loss possible.	Fire Department responds in 3-5 minutes. High fire loss possible.
Optical detection system fails	Fire Department responds in 3-5 minutes. High fire loss possible.	System activates as designed for fires. Fire loss moderate to negligible.
Detection system repeatedly false-activates.	Slower Fire Department response; personnel injury and high fire loss possible, significant clean–up required before hangar can be used, system activates as designed for fires. Fire loss moderate.	System activates as designed for fires. Fire loss moderate to negligible.
Heavy black smoke obscures fire scene. Fire Department cannot detect exact location of fire.	System activates. Fire loss moderate.	System activates. Fire loss moderate to negligible.
Spill fire not directly under aircraft	System activates. Fire loss high.	System activates. Fire loss moderate to negligible.
Fire too large for Fire Department to suppress	Not applicable. System operates as designed for large fires. Fire loss moderate.	Not applicable. System operates as designed for large fires. Fire loss moderate to negligible.
Fire traps personnel inside aircraft.	System activates as designed for fires. Personnel likely to escape injury.	System activates as designed for fires. Personnel likely to escape injury.
Hangar doors closed and inoperative (handlines through personnel doors remain available.)	System activates as designed for fires. Fire loss moderate.	System activates as designed for fires. Fire loss moderate to negligible.
Fire inside aircraft; maintenance personnel telephone report.	After flame penetrates skin of involved aircraft, system activates without effect. High fire loss probable.	After flame penetrates skin of involved aircraft, system activates as designed to protect adjacent aircraft and hangar. Fire loss likely limited to the involved aircraft. High fire loss possible.
Maintenance personnel inadvertently park AGE equipment and block fire detectors.	System activation delayed, blockage of the optical detector would also block agent discharge. High fire loss possible.	System activates as designed for fires. Fire loss moderate to negligible.
Detection system activates while Fire Department on standby for flight operations.	System activates. Fire loss moderate.	System activates. Fire loss moderate to negligible.
Saboteur covers optical fire detectors, starts fire	Fire Department responds in 3-5 minutes. High fire loss possible.	System activates as designed for fires. Fire loss moderate to negligible.

Table 15. Hangar Fire Suppression Control Method Event Scenarios (Continued)

SCENARIO	MAFFE	INSTALLED UNDERWING
Saboteur disables fire suppression system, starts fire	Fire Department responds in 3-5 minutes. High fire loss possible.	Trouble alarm expected at Fire Department, but no automatic fire suppression response. High fire loss possible.
Detection system activates while Fire Department engaged on another fire.	System activates as designed for fires. Fire loss moderate.	System activates as designed for fires. Fire loss moderate to negligible.
Changes in aircraft assigned to the Wing lead to detection system devices not properly spaced and oriented for likely sources of fire.	System activates as designed for fires. Fire loss high to moderate.	System activates as designed; however, underwing nozzles may be improperly oriented. Fire loss may increase but should remain moderate.
JP-4 fuel spill ignites from an ignition source under an aircraft.	System activates as designed for fires. Fire loss moderate.	System activates. Fire loss moderate to negligible.
JP-4 fuel spill ignites from an ignition source not under an aircraft.	System activates as designed for fires. Fire loss catastrophic possible.	System activates. Fire loss moderate to negligible.
Human error causes the Fire Department to respond to the wrong hangar or to arrive late.	System activates as designed for fires. Fire loss moderate.	System activates as designed for fires. Fire loss moderate to negligible.

The team identified the various aspects of risk affected by each control method; then determined a new probability and severity for each aspect if each control option were implemented. Results are presented in Tables 16 and 17.

Table 16. Control Measure Results — MAFFE

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
1	a	(2)	Does not understand procedural guidance for placement of MAFFE	Use currently designed and available installed system instead of the MAFFE	II	C	High	IV	E	Low
				Require the manufacturer provide more specific procedural guidance and training checklists. Use guidance and checklists to provide training.	II	C	High	II	D	Medium
1	b	(2)	Improper emer-gency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Use ancillary automatic warning devices.	II	C	High	IV	E	Low
				Provide training and practice on use of the MAFFE	II	C	High	II	D	Medium
1	b	(5)	Workload negates importance of MAFFE handling	Provide training and practice on use of the MAFFE	II	C	High	II	D	Medium
				Hire more people or reduce workload	II	C	High	III	E	Low

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
2	b	(1)	Maintenance person in aircraft when hangar fire occurs	Defuel the aircraft before towing it into the hangar	I	D	High	III	E	Low
				Delox the aircraft before towing it into the hangar	I	D	High	III	E	Low
				Defuel and delox the aircraft	I	D	High	IV	E	Low
2	b	(4)	Foam pattern disrupted	Provide physical barriers to restrict obstructions	I	A	Extreme	III	C	Medium
				Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)	I	A	Extreme	III	C	Medium
				Mark floor to show areas available for maintenance portable equipment positioning	I	A	Extreme	III	C	Medium
				Provide training on procedures for correct support equipment placement	I	A	Extreme	I	B	Extreme

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
2	b	(5)	MAFFE unable to control fire	Defuel the aircraft before towing it into the hangar	I	C	High	III	E	Low
				Use more units	I	C	High	III	D	Low
2	c	(1)	Hangar crowding	Delay maintenance	I	D	High	III	E	Low
				Build more hangars	I	D	High	III	E	Low
2	c	(2)	Conflicting maintenance operations	Limit number of aircraft in hangar	II	B	High	II	B	High
				Provide training and practice on use of the MAFFE	II	B	High	II	C	High

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
2	d	(1)	Internal aircraft fires	Post guards to avoid sabotage	I	C	High	II	D	Medium
				Require person to be present when aircraft is powered	I	C	High	III	C	Medium
				Increase preventive maintenance on high failure parts	I	C	High	I	D	High
				Provide training and practice on use of the MAFFE	I	C	High	I	D	High
				Enforce correct maintenance procedures	I	C	High	I	D	High
3	a	(2)	Inadequate foam coverage due to incorrect placement	Use more units	I	A	Extreme	III	D	Low
				Use equipment which does not require movement	I	A	Extreme	III	D	Low

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
3	a	(4)	MAFFE activated/deactivated erroneously by surrounding activity	Use equipment with more effective switch protection	I	D	High	II	E	Low
				Provide an expanded clear zone around the MAFFE	I	D	High	II	D	Medium
				Check system more frequently	I	D	High	II	E	Low
3	a	(5)	Inadvertent or erroneous shutdown	Use equipment with more effective switch protection	I	D	High	III	E	Low
				Use equipment which provides power loss alarms or shutoff alarms	I	D	High	II	E	Low
				Check system more frequently	I	D	High	II	E	Low
3	a	(10)	Failure to control fire	Use more MAFFE units	I	B	Extreme	II	C	High

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
3	a	(11)	Failure to control fire	Use more MAFFE units	I	B	Extreme	II	C	High
3	a	(12)	Failure to control fire	Reduce Fire Department response time	I	B	Extreme	II	D	Medium
3	c	(4)	Aircraft not appropriately protected	Delay maintenance until spotting plan developed	I	D	High	III	E	Low
4	a	(1)	System cannot be used when needed without violating public law	Obtain appropriate approvals. Submit notification to Congress prior to implementing the system AF-wide	I	C	High	IV	E	Low

Table 16. Control Measure Results — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
5	a	(1)	Fuel spills	Restrict use of fuel in all hangar operations	III	A	High	III	C	Medium
				Use safety or warning devices (i.e.: combustible vapor detectors)	III	A	High	III	A	High
				Use fuels only outdoors. Bring only unfueled aircraft into hangars	III	A	High	IV	E	Low
				Obtain commercial insurance for fires due to fuel spills	III	A	High	III	A	High

Table 17. Control Measure Results — Installed Underwing System

			HAZARDS	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
2	a	(2)	System components freeze	Provide temperature warning per current criteria	I	D	High	I	E	Medium
2	b	(1)	Maintenance person in aircraft when fire occurs	Defuel the aircraft before towing it into the hangar	I	D	High	III	E	Low
				Delox the aircraft before towing it into the hangar	I	D	High	III	E	Low
				Defuel and delox the aircraft	I	D	High	III	E	Low

Table 17. Control Measure Results — Installed Underwing System (Continued)

			HAZARDS	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
2	b	(4)	Foam pattern disrupted	Install additional nozzles to support enhanced system performance	II	A	Extreme	III	C	Medium
				Provide physical barriers to restrict obstructions	II	A	Extreme	III	C	Medium
				Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)	II	A	Extreme	III	C	Medium
				Mark floor to show areas available for maintenance portable equipment positioning	II	A	Extreme	III	C	Medium
				Provide training on procedures for correct support equipment placement	II	A	Extreme	II	B	High
				Add mobile systems to enhance coverage	II	A	Extreme	III	C	Medium
2	c	(1)	Hangar crowding	Delay maintenance	I	D	High	III	E	Low
				Build more hangars	I	D	High	III	E	Low
2	c	(2)	Conflicting maintenance operations	Limit number of aircraft in hangar	II	B	High	II	B	High
				Provide training and practice on use of the system	II	B	High	II	C	High
2	d	(1)	Internal aircraft fires	Post guards to avoid sabotage	I	C	High	II	D	Medium
				Require person to be present whenever power is applied to the aircraft	I	C	High	III	B	Medium
				Increase preventive maintenance on high failure parts	I	C	High	I	D	High
				Provide training and practice on use of the system	I	C	High	I	D	High
				Enforce correct maintenance procedures	I	C	High	I	D	High

Table 17. Control Measure Results — Installed Underwing System (Continued)

			HAZARDS	CONTROL OPTIONS	Uncontrolled Severity	Uncontrolled Probability	Uncontrolled RAI	Controlled Severity	Controlled Probability	Controlled RAI
3	a	(8)	Component fails or incorrect installations are completed	Increase frequency of maintenance or test procedures	I	C	High	III	D	Low
				Provide training and practice on use of the system	I	C	High	I	D	High
				Use equipment with more effective switch protection	I	C	High	III	E	Low
				Use equipment which provides power loss alarms or shutoff alarms	I	C	High	III	E	Low
				Check system more frequently	I	C	High	II	D	Medium
3	b	(2)	System not maintained properly	Complete all appropriate maintenance on schedule	II	B	High	III	D	Low
				Stress the priority of maintenance (maintenance is of equal importance of the equipment it protects)	II	B	High	II	C	High
				Provide training and practice on use of the system	II	B	High	II	C	High
				Provide technical orders to support the system	II	B	High	III	D	Low
3	c	(1)	Equipment mal-functions (inadequate tech data)	Require appropriate, comprehensive technical data be provided with each system	I	C	High	III	D	Low
4	b	(4)	Equipment not usable	Require MAJCOM noti-fication of system shut-downs	I	D	High	I	D	High
				Delay, postpone, or cancel maintenance until the system is repaired	I	D	High	III	E	Low
				Institute a fire watch schedule	I	D	High	I	D	High

STEP 3: ANALYZE CONTROL MEASURES

ACTION 3: PRIORITIZE RISK CONTROLS

The team used the guidance from AFP 91-215 to prioritize the risk controls. They decided to evaluate only those control options identified in previous steps, which reduced risk to either a "low", or a "medium" level. The control options were evaluated against the following criteria:

- Is the control consistent with mission objectives?
- Does the control provide for optimum use of available resources (manpower, material, equipment, money, and time)?
- Does the control reduce the risk to an acceptable level?

Against these criteria, the team evaluated each hazard control option.

- If the control option satisfied all three criteria, it was assigned a priority of 3.
- If the control option satisfied two of the three criteria, it was assigned a priority of 2.
- If the control option satisfied only one of the criteria, it was assigned a priority of 1.
- If the control option satisfied none of the criteria, it was assigned a priority of 0.

Additionally, tradeoffs were discussed, such as balancing costs and benefits as they affect mission performance, cost and continued risk exposure.

The results of the Risk Control Prioritization are shown in Tables 18 and 19.

Table 18. Control Measures Priority — MAFFE

			HAZARDS/MAFFE	**CONTROL OPTIONS**	**CONTROLLED RAI**	**PRIORITY 3 = Highest 0 = Lowest**	**COMMENTS**
1	a	(2)	Does not under-stand procedural guidance for placement of MAFFE	Use currently designed and available installed system instead of the MAFFE	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Require the manufacturer provide more specific procedural guidance and training checklists. Use guidance and checklists to provide training.	Medium	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
1	b	(2)	Improper emergency response (i.e.: inappropriate CEF notification, incorrect equipment use)	Use ancillary automatic warning devices.	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Provide training and practice on use of the MAFFE	Medium	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide optimum use of resources.
1	b	(5)	Workload negates importance of MAFFE handling	Provide training and practice on use of the MAFFE	Medium	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide optimum use of resources.
				Hire more people or reduce workload	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
2	b	(1)	Maintenance person in aircraft when hangar fire occurs	Defuel the aircraft before towing it into the hangar	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Delox the aircraft before towing it into the hangar	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Defuel and delox the aircraft	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
2	b	(4)	Foam pattern disrupted	Provide physical barriers to restrict obstructions	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Mark floor to show areas available for maintenance portable equipment positioning	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
2	b	(5)	MAFFE unable to control fire	Defuel the aircraft before towing it into the hangar	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources
				Use more units	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources
2	c	(1)	Hangar crowding	Delay maintenance	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Build more hangars	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
2	d	(1)	Internal aircraft fires	Post guards to avoid sabotage	Medium	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Require person to be present when aircraft is powered	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
3	a	(2)	Inadequate foam coverage due to incorrect placement	Use more units	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Use equipment which does not require movement	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
3	a	(4)	MAFFE activated/deactivated erroneously by surrounding activity	Use equipment with more effective switch protection	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Provide an expanded clear zone around the MAFFE	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Check system more frequently	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
3	a	(5)	Inadvertent or erroneous shutdown	Use equipment with more effective switch protection	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Use equipment which provides power loss alarms or shutoff alarms	Low	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide optimum use of resources.
				Check system more frequently	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
3	a	(10)	Failure to control fire	Use more MAFFE units	High		Fails to reduce risk to an acceptable level
3	a	(11)	Failure to control fire	Use more MAFFE units	High		Fails to reduce risk to an acceptable level
3	a	(12)	Failure to control fire	Reduce Fire Department response time	Medium	1	Reduces risk to an acceptable level Not consistent with mission objectives Fails to provide optimum use of resources.
3	c	(4)	Aircraft not properly protected	Delay maintenance until spotting plan developed	Low	1	Reduces risk to an acceptable level Not consistent with mission objectives Fails to provide optimum use of resources.

Table 18. Control Measures Priority — MAFFE (Continued)

			HAZARDS/MAFFE	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY 3 = Highest 0 = Lowest	COMMENTS
4	a	(1)	System cannot be used when needed without violating public law	Obtain appropriate approvals. Submit notification to Congress prior to implementing the system AF-wide	Low	**	See comments below.
5	a	(1)	Fuel spills	Restrict use of fuel in all hangar operations	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.
				Use fuels only outdoors. Bring only unfueled aircraft into hangars	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives Fails to provide optimum use of resources.

Table 19. Control Measures Priority — Installed Underwing System

			HAZARDS	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY	COMMENTS
2	a	(2)	System components freeze	Provide temperature warning per current criteria	Medium	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
2	b	(1)	Maintenance person in aircraft when fire occurs	Defuel the aircraft before towing it into the hangar	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Delox the aircraft before towing it into the hangar	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.

Table 19. Control Measures Priority — Installed Underwing System (Continued)

			HAZARDS	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY	COMMENTS
				Defuel and delox the aircraft	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
2	b	(4)	Foam pattern disrupted	Install additional nozzles to support enhanced system performance	Medium	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide for optimum use of resources.
				Provide physical barriers to restrict obstructions	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Provide 2 foot clearance above the floor (i.e.: rack all maintenance equipment)	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Mark floor to show areas available for maintenance portable equipment positioning	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Add mobile systems to enhance coverage	Medium	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide for optimum use of resources.

Table 19. Control Measures Priority — Installed Underwing System (Continued)

			HAZARDS	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY	COMMENTS
2	c	(1)	Hangar crowding	Delay maintenance	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Build more hangars	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
2	d	(1)	Internal aircraft fires	Post guards to avoid sabotage	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Require person to be present whenever power is applied to the aircraft	Medium	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide for optimum use of resources.
3	a	(8)	Component fails or incorrect installations are completed	Increase frequency of maintenance or test procedures	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.
				Use equipment with more effective switch protection	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Use equipment which provides power loss alarms or shutoff alarms	Low	2	Reduces risk to an acceptable level. Consistent with mission objectives. Fails to provide for optimum use of resources.
				Check system more frequently	Medium	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.

Table 19. Control Measures Priority — Installed Underwing System (Continued)

			HAZARDS	CONTROL OPTIONS	CONTROLLED RAI	PRIORITY	COMMENTS
3	b	(2)	System not maintained properly	Complete all appropriate maintenance on schedule	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
				Provide technical orders to support the system	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
3	c	(1)	Equipment malfunctions (inadequate tech data)	Require appropriate, comprehensive technical data be provided with each system	Low	3	Reduces risk to an acceptable level. Consistent with mission objectives. Provides for optimum use of resources.
4	b	(4)	Equipment not usable	Delay, postpone, or cancel maintenance until the system is repaired	Low	1	Reduces risk to an acceptable level. Not consistent with mission objectives. Fails to provide for optimum use of resources.

STEP 4: MAKE CONTROL DECISIONS

ACTION 1: SELECT RISK CONTROLS

This step of risk analysis involves two major dimensions: (1) selecting the risk controls to apply from among those developed in Step 3; and (2) deciding whether or not to accept the residual risk in a mission or project after applying the selected controls. Decisions should be made with an awareness of hazards and how important hazard control is to mission success or failure (cost versus benefit).

Mobile Automatic Foam Fire Extinguisher (MAFFE)

In general, some risks cannot be reduced to acceptable levels. Some of the risk controls identified will not reduce the risk levels without changes to the MAFFE design, unsatisfactory impact to manning levels, unsatisfactory impact on operations, and unsatisfactory impact on maintenance procedures. The MAFFE alternative presents unacceptable risk levels even if all identified controls are implemented. Two issues pose extreme risks, they are:

- Disruption of the foam pattern
- Inadequate foam coverage because of misplacement of the MAFFE unit in relation to the protected aircraft

In addition to these unacceptable risk levels, the following issues were also included in the team's deliberation:

- The MAFFE alternative's unsatisfactory impact on operations and on maintenance procedures were verified by through the results of the field survey. The MAFFE concept package requires unit maintenance be provided by the users, which is imposes unacceptable burdens on the maintenance community. As day-to-day maintenance functions are assigned priorities, MAFFE support tasks might be routinely delayed as maintenance personnel complete higher priority jobs.
- Margins of safety are reduced to a level near the theoretical minimums in terms of density and quantity of foam delivered to a fire. Serious concern remains that two or more MAFFE units would interact to disrupt the foam pattern needed for fire suppression. Historical data shows that when multiple units of fire fighting equipment are used at marginally acceptable angles of attack, the units can counteract each other and spread the fire. Additionally, the MAFFE units and overhead water sprinkler system would interact to dilute the foam and spread the fire, even when MAFFE units positioned optimally.
- An idea presented during this ORM — that the MAFFE could be used in Air Force hangars where currently there is no fire suppression — was incorrect. The basic concept that “any protection is better than nothing” was invalidated during this ORM: the resultant data showed that an expensive system, which does not meet minimum requirements and levies additional taskings against maintenance, is an unacceptable alternate.
- Life cycle costs of the MAFFE are unacceptably high. Additional requirements in the maintenance infrastructure, — specifically, training requirements and long-term maintenance workload increases — counteract any short-term benefits associated with implementation costs. Calculated life cycle costs include this increased maintenance tasking.

Table 20 provides several key performance factors and technical standards from NFPA 409, *Standard for Aircraft Hangars*, and compares the MAFFE and current Air Force installed systems with these performance factors. The MAFFE does not meet any of the minimum performance criteria of this national standard. The current Air Force criteria satisfy the minimum performance criteria in all underwing applications, but not in overhead applications. (Current Navy tests have proven Air Force system performance against a spill fire will be equivalent to NFPA 409 system performance).

> **Note:** Several hazards will remain High Risk unless severe restrictions are placed on maintenance actions in the hangar. Although the probability of these hazards could be very small, the severity is sometimes very large. Current Air Force philosophy is to accept this risk. No change to the current Air Force philosophy for these risks is proposed in this ORM.

The MAFFE could be expected to control a small fire under the aircraft, but the Air Force currently accepts this risk since these fires can be extinguished easily with in-place 150-pound wheeled fire extinguishers. Fire Department personnel would extinguish the fire upon arrival and minimize damage. The associated avoidable risk is assumed to result in moderate to negligible damage to an incident aircraft, and the Air Force is currently accepting this risk. Given that the MAFFE could minimize the loss to the aircraft without human intervention or in the absence of maintenance personnel until fire department arrival, the MAFFE could be considered as providing better risk reduction in this case. However, the cost associated with providing the MAFFE does not justify the implementation of the unit on a full-scale basis when it minimizes only this specific type of loss. The Air Force approach represents a compromise between the operational goals of reducing false or inadvertent suppression system activation while at the same time protecting aircraft. Use of the MAFFE would not comply with this philosophy and would provide insufficient return on investment. It would require the Air Force to accept an extreme risk level similar to unprotected hangars.

Table 20. Performance Comparison of Systems to National Standards

PERFORMANCE FACTOR	STANDARD	MAFFE	SAFETY FACTOR	INSTALLED SYSTEMS	SAFETY FACTOR
Minimum application rate	• 0.10 per NFPA Standard 409 as a supplemental to a 0.16 overhead deluge system providing a total of 0.26 gpm per square foot of floor area. • 0.10 per NFPA Standards 11, 403. • 0.10 per USAF ETL 98-7 & 98-6. • Scientific minimum extinguishing quantity 0.01 to 0.02 gpm per square foot of fuel surface area under ideal laboratory conditions.	0.02 – 0.03 gpm per square foot	0.3	0.10 gpm per square foot	1.0

Table 20. Performance Comparison of Systems to National Standards (Continued)

PERFORMANCE FACTOR	STANDARD	MAFFE	SAFETY FACTOR	INSTALLED SYSTEMS	SAFETY FACTOR
Minimum application duration	• 10 minutes NFPA 409 • Scientific minimum extinguishing 60 seconds under ideal laboratory conditions.	Approximately 105 seconds	0.2	10 minutes	1.0
Minimum application area	• Shadow area of the aircraft plus overhead deluge system covering entire hangar floor	Shadow area of the aircraft	-	Entire hangar floor area	-
Practical application area	• Free burning JP-8 can generate sufficient energy at 20 feet to cause second degree burns, damage composite materials and aluminum aircraft skins at 65 feet	Shadow area of the air-craft plus a small area directly in front of the MAFFE unit	Subminimal	Shadow area of the aircraft plus not less than 20 feet on all sides of the aircraft. In most cases complete coverage of the hangar floor	Minimum plus

Installed Underwing Suppression Systems

In general, the one extreme risk can be reduced to acceptable level with some adverse impact to resources (funding). Half of the remaining risk controls identified will reduce some risk levels only with changes to the Underwing Suppression System design, unsatisfactory impact to manning levels, unsatisfactory impact on operations, and unsatisfactory impact on maintenance procedures. The other half of the remaining risk controls identified will have no unsatisfactory impact.

Overall, the installed underwing system is judged effective in controlling risk within current Air Force hangar protection risk limits for the following reasons:

- This approach is preferred by the field because it has minimal impact on manning. This important issue was verified through the results of the field survey.
- Only one risk was judged an Extreme Risk, which could be reduced to Medium Risk through proper system design, which compensates for foam pattern disruption, and continuing overlapping foam coverage.
- The basic concept that the currently installed underwing systems require ongoing maintenance was reiterated during this ORM. Failure to provide such maintenance invalidates the risk assessment presented herein, since the system was assumed installed and functioning correctly when it was assessed.
- Table 19 provides several key performance factors and technical standards from the NFPA 409. The installed underwing system meets or exceeds the minimum criteria of this national standard.

- Use of suppression systems is consistent with the current standard to control fire risk in Air Force hangars, which employs the following strategy:

  For fires less than 100 square feet:
  - Fire is extinguished by building occupants or by portable fire suppression units

    Note: Installed fire suppression systems cannot control fires in large hangars because early stage fires cannot be reliably detected.

  For fires greater than or equal to 100 square feet:
  - Installed facility fire suppression systems activate to:
    - Contain fire growth to less than 400 square feet
    - Control the fire to prevent damage to adjacent aircraft and facility
    - Support the Fire Department until final extinguishment

  For all fires:
  - The Fire Department accomplishes final extinguishment and cleanup.

The installed underwing suppression system is not expected to respond to a small fire under the aircraft unless activated by maintenance personnel. Instead, maintenance personnel are expected to extinguish these small spill fires using the in place 150-pound, wheeled fire extinguishers. If maintenance personnel fail to extinguish the small fire and fail to manually activate the installed system, the fire will grow and may damage incident aircraft before the installed system responds. The overhead sprinkler system and installed underwing suppression system will prevent catastrophic loss of incident aircraft, damage to adjacent aircraft, and structural damage to the hangar. Incident aircraft also might be saved, but would probably be damaged. This Air Force approach represents a compromise between the operational goals of reducing false or inadvertent suppression system activation, while at the same time protecting aircraft and mission capability. It provides an acceptable return on investment compared to the expected costs from losing a hangar and multiple aircraft every few years. It does not require the Air Force to accept an Extreme Risk for an aircraft hangar.

Hangar Protection by Private Industry

In NFPA 409, private industry has recognized that providing installed suppression systems or no systems at all are the only accepted options. The alternatives of installing suppression systems or no systems are generally dictated by the commercial insurance industry. Commercial hangars comparable in size to Air Force hangars are required to have suppression systems to obtain insurance. Additionally, these suppression systems are more “aggressive” than systems satisfying current Air Force criteria. The sector of the insurance industry which protects HPR (highly protected risks), such as commercial aircraft hangars, is extremely competitive — yet not a single insurer or broker will offer insurance to a customer without an installed fire suppression system. Discussions were held with Factory Mutual System, Industrial Risk Insurer, Johnson & Higgins, and M&M Protection on their requirements to offer to insure or broker insurance for a hangar. When asked if they would insure hangars built to the current, less aggressive Air Force systems, they indicated it would depend on who the client was and whether the client was willing to pay an increased premium. The Air Force currently accepts more risk than private industry to achieve the operational goal of reducing false or inadvertent suppression system activation.

STEP 4: MAKE CONTROL DECISIONS

ACTION 2: MAKE RISK DECISION

The team considered the results of the risk analysis as presented in the previous steps and actions, and used additional information to evaluate the risk, as presented in ETLs 98-7 and 98-8.

Attachment 2 discusses the costs of providing installed underwing systems in new and existing hangars. The data suggests three possibilities: (1) the hangar has no suppression system; (2) the hangar has an overhead sprinkler system only; or (3) the hangar has both overhead sprinkler and installed underwing suppression systems but the underwing suppression systems need complete replacement due to age or condition. In all cases, the costs of providing installed underwing systems are considered acceptable.

Life cycle costs of the MAFFE are unacceptably high. Additional requirements in the maintenance infrastructure, — specifically, training requirements and long-term maintenance workload increases — counteract any short-term benefits associated with implementation costs. Calculated life cycle costs include this increased maintenance tasking.

Life cycle costs of the installed Underwing Suppression System are acceptable. Although initial investment appears high, total life cycle cost for protecting the current entire Air Force inventory had already been judged acceptable, particularly when compared to the cost of losing a single aircraft.

Attachment 2 also discusses the cost of deploying and maintaining the MAFFE as a fire suppression system in Air Force hangars housing aircraft. The expected costs of the MAFFE are considered not acceptable.

> **Note:** Attachment 2 does NOT address the additional cost of mission loss or the cost of personnel losses — only the dollar cost of loss to aircraft and facilities.

Attachment 3 presents results of a questionnaire sent to Civil Engineering (CE), Aircraft Maintenance (LG), and Aircraft Operations (XO) flights on aircraft hangar fire suppression operational parameters. Few XO responses were received, but the 22 CE and 26 LG responses did not support the deployment of the MAFFE.

The Hughes Associates report of the test program concluded that there are serious concerns related to operational viability of the MAFFE, particularly its slim margin of safety, operating near the laboratory theoretical absolute minimum for AFFF solution. National standards, based on extensive full-scale fire testing by Factory Mutual Research, Naval Facilities Engineering Command, and the Air Force, clearly demonstrate the minimum performance/design factors for consistent, assured, successful fire control and extinguishment to be almost 10 times the minimum theoretical values. Based on this, the Hughes report concluded the MAFFE could not be considered a replacement for current underwing fire suppression systems. The report further concluded that the technical basis for hangar fire protection would have to be relaxed, increasing the acceptability of aircraft damage and loss, if a concept like the MAFFE was considered. The survey of Air Force field activities clearly demonstrated the very low acceptability of aircraft damage — less than 20 percent damage for an aircraft in direct contact with flame and less than 7 percent damage for adjacent aircraft. The MAFFE cannot achieve this level of protection except in a very few cases. Installed underwing systems are reasonably capable of preventing this level of damage.

Although the team identified theoretical control measures for use of the MAFFE, these control measures do not eliminate some fundamental problems associated with the possible application of MAFFE to hangar fire protection concepts. The team agreed with the results in the field survey that concluded significant impact on manpower, current operations, and current maintenance procedures would be unacceptable to the Air Force.

Given the inability of the MAFFE concept to resolve the functional issues identified in the ORM, and the critical issue of acceptability to the maintenance community who would have to bear the majority of the operational burden to implement the MAFFE, the MAFFE is not considered a practical alternative to currently approved protection.

Conclusions

- Use of an installed underwing suppression system is a practical approach to Air Force hangar fire protection.
- Use of a MAFFE system is not a practical approach to Air Force hangar fire protection.
- Continued use of the current criteria for fire suppression systems (NFPA Group II standards, as detailed in ETL 98-7) is appropriate. NFPA Group II standards are national consensus standards in common use commercially.
- No acceptable commercial off-the-shelf (COTS) technology exists to replace current hanger protection. A Major Command proponent could establish a formal Statement of Need (SON) to energize the Air Force research development and acquisition (RD&A) to develop an acceptable technology to enhance hangar protection concepts to accommodate current and future mission requirements.

STEP 5: IMPLEMENT RISK CONTROLS

ACTION 1: MAKE IMPLEMENTATION CLEAR

Technical options are implemented according to the technical criteria. Criteria are provided for design agents', construction agents', and architects' and engineers' use in aircraft hangar construction and renovation projects. Technical criteria usually are issued in ETLs and made available via the AFCESA worldwide web homepage, and the Construction Criteria Base database through the National Institute of Building Sciences. These sources are available free to Federal contractors.

Implementation of the criteria will be measured by evaluation of construction project technical design documents to determine if the revised criteria are being properly incorporated into the projects.

Because this involves technical criteria for facility construction, it is not possible to measure the effect of implementation directly. Hangar fire events are infrequent and it may be several years before a significant fire threatens a facility constructed to these revised standards.

Adequate protection of hangars and aircraft will not occur unless hangar fire suppression systems are maintained. To support maintenance, a revision to AFI 32-1059, *Maintenance of Fire Protection Systems* is targeted for completion by the end of calendar year 1998 to ensure adequate guidance for maintenance is in place.

Implementation of adequate maintenance will continue to be tracked at base level using the base's Recurring Maintenance System.

STEP 5: IMPLEMENT RISK CONTROLS

ACTION 2: ESTABLISH ACCOUNTABILITY

MAJCOM Program Managers

In accordance with guidance in AFI 32-1032, *Planning and Programming Real Property Maintenance Projects Using Appropriated Funds (APF)*, MAJCOM program managers are responsible for ensuring the most current technical guidance is used in construction and renovation projects. The MAJCOM program manager directs the design manager for each project to include the guidance. Program Mangers should also participate in criteria reviews because the potential dollar losses and mission impact associated with newer aircraft are significantly greater.

HQ AFCESA/CESM

HQ AFCESA/CESM is preparing a revision to AFI 32-1059, *Maintenance of Fire Protection Systems*, and will review and update ETLs 98-7 and 98-8 as necessary to address future aircraft, as well as contribute to future revisions of NFPA 409 and MIL-HDBK-1008C. HQ AFCESA/CESM will also monitor and review technological advances and the results of ongoing tests (including fire test results of other agencies) to see if additional simplifications or cost reductions for hangar fire suppression systems can be implemented without undue risk. HQ AFCESA will coordinate criteria reviews with the MAJCOMs and applicable Program Executive Officers (PEOs).

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers maintains a Center of Technical Expertise to ensure that Air Force hangars are designed, built, and accepted in accordance with current standards and criteria.

Naval Safety Center

Collection and record keeping of fire incident data to support additional evaluation of risk controls is performed by the installation's Fire Department, and is maintained by Naval Safety Center, Norfolk, Virginia.

Base Civil Engineer

Maintenance of installed systems is accomplished using the Recurring Maintenance System to ensure systems remain operational.

366 TS, Sheppard AFB

Training on maintenance procedures and techniques is provided. Training courses are maintained current to approved criteria.

Program Executive Officers (PEOs)

PEOs should coordinate critical factors such as susceptibility to thermal damage with AFCESA to ensure protection criteria evolve in parallel with current and future airframe development. PEOs should review and coordinate on the periodic revalidation of the protection criteria on the performance and operation of their aircraft platforms. This includes projection for time/temperature versus loss data.

STEP 5: IMPLEMENT RISK CONTROLS

ACTION 3: PROVIDE SUPPORT

HQ USAF/IL/XO/SE approved the current hangar fire protection approach in February 1998.

Technical criteria requiring changes to systems maintenance procedures will be provided regularly to the 366 TS, Sheppard AFB, Texas, for inclusion in the fire system maintenance and the fire alarm maintenance courses. These courses provide specialized 7-level hands-on-instruction to base level craftsmen in the inspection, test, maintenance, and repair of fire protection systems installed in Air Force facilities.

Feedback into the process is provided by formal ground mishap investigations related to aircraft hangar fires and accidental system activation. Informal feedback is provided through evaluations and loss reports of events not requiring formal ground mishap investigations. Additional feedback is sometimes available from maintenance technicians, fire inspectors, and safety inspectors conducting periodic maintenance and inspections.

Air Force fire protection personnel responsible for hangars will hold meetings periodically to share lessons learned and determine emergent needs for changes in technical guidance.

STEP 6: SUPERVISE AND REVIEW

ACTION 1: SUPERVISE

This step is yet to occur. Future action should be taken to ensure:

- Controls are effective and remain in place.
- Changes, which require further risk management, are identified.
- Ineffective risk controls are corrected.

Re-initiate risk management steps in response to new hazards.

STEP 6: SUPERVISE AND REVIEW

ACTION 2: REVIEW

This step is yet to occur. Future actions may include:

- Complete a systematic review.
- Accomplish a cost/benefit analysis to determine if risk and cost are in balance.
- Recognize changes in the system and apply risk management controls.
- Determine if actual costs are in line with expectations.
- Determine what effect control measures have had on mission performance.
- Focus on the aspect of mission performance that the control measure was designed to improve.
- Use feedback information to determine when additional analysis and correction steps are needed.
- Quantify how effectively controls eliminated hazards, improved mission success, enhanced capabilities, or reduced risk.

CONCEPT PACKAGE

FOR USE OF A MOBILE AUTOMATIC FIRE EXTINGUISHER

IN AIRCRAFT HANGARS

NOTE: This concept package is based on the breadboard prototype tested and does not necessarily represent the final performance and requirements of an optimized MAFFE device. This concept package is provided to give survey participants a generalized view of how a MAFFE might be used and the support that may be required to implement such a device.

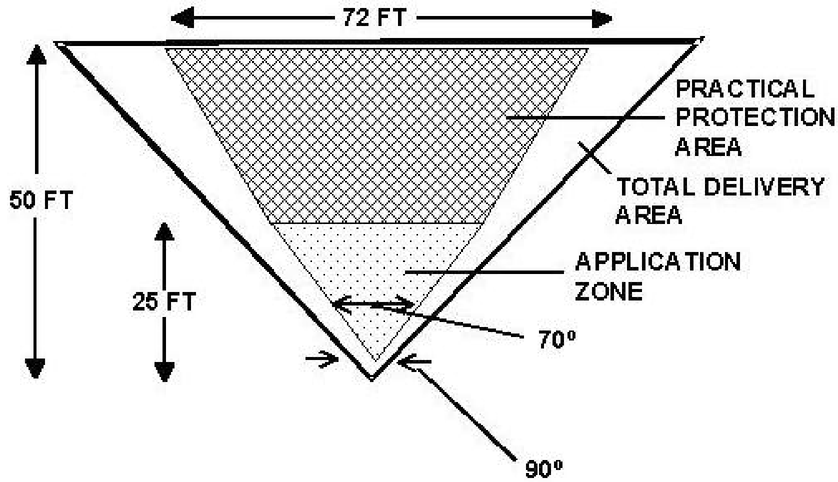
The breadboard prototype MAFFE (above) is shown beside a standard 150-pound Halon 1211 flight line extinguisher. The 150-pound extinguishers would continue to be used in hangars to provide a clean agent for small fires.

BACKGROUND

To evaluate the potential use of a mobile automatic fire extinguisher in aircraft hangars to replace installed fire protection features, it is necessary to develop a conceptual plan for how such a device might be used. This conceptual plan has not received coordination from either the civil engineering operations, fire protection operations, or the aircraft maintenance communities.

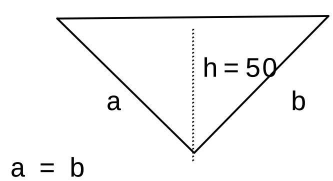
PRACTICAL PROTECTION AREA

The practical area of protection provided by the system is 1350 square feet. This is based on a 90-degree sweep pattern for the nozzle. The total delivery area is 45 degrees either side of the nozzle center line by 50 feet on the centerline. However, the practical delivery area is only 35 degrees either side of the centerline of the nozzle. The practical delivery area is smaller because the unit can't be precisely positioned and this allows only a one-degree flexibility in positioning. This practical delivery area is further divided into an application zone, the first 25 feet from the unit which must be clear and the practical protection area the zone between 25 and 50 feet from the nozzle.



AGENT APPLICATION

AFFF solution is delivered over a total area of 2450 square feet.



AREA = ½ a b = ½ (h/sin 45)^{2} = ½ (70)^{2} = 2450 square feet.

Application rate (gallons per minutes per square foot) = (unit capacity/area)/application time
Application rate = (120/2450)/1.75 = 0.028 gpm/square foot

CONCEPT OF ACQUISISTION

Units will be a commercially available product listed/approved by an independent third party laboratory (UL, FM) as meet specific performance requirements.

Units will be purchased by the installation engineering organization. Two per each aircraft hangar parking position, plus one for each 1,000 square feet or portion of aircraft shadow area over 1500 square feet. The installation will also require 10 percent spare units rounded to the next whole number, to support scheduled maintenance and repair.

CONCEPT OF MAINTENANCE

Maintenance, including repair and re-servicing, will be accomplished by the base engineering organization in the same manner as portable and flight line fire extinguisher.

Since the unit includes 12-volt automotive batteries, on-base extinguisher maintenance shops must be modified for the safe storage and handling of acid filled batteries, including the provision of emergency showers and eye wash stations. The only special tools required will include:

- Floor jacks and stands to permit the replacement of deflated tires and damages axles.
- Nitrogen bottle-lift to load and remove the bottle from the unit. The bottles are handled in a vertical configuration and carried on the unit in a horizontal configuration.

Special maintenance, such as hydrostatic testing of the main tank (pressure vessel), will be accomplished by an outside contractor.

CONCEPT OF OPERATIONS

The installation fire protection flight will provide annual training to all aircraft hangar maintenance personnel on the positioning, operator maintenance, and manual operation of these units.

The installation fire protection flight and aircraft maintenance personnel must jointly develop a location plan for each aircraft parking position in the hangar.

The installation engineering activity must mark the hangar floor with unit positioning markings for each aircraft parking position. The application zone discharge area must be marked on the floor to prevent obstruction in this critical area.

The installation fire protection flight will deliver the required units to each hangar and provide replacement units when notified by aircraft maintenance control of an inoperative unit.

The aircraft maintenance personnel will position the units based on the aircraft serviced.

- Move units for each aircraft movement including adjacent units if necessary.

The aircraft maintenance personnel will conduct the daily and operator maintenance on the unit.

- Daily tests of all units for adequate battery power. Operate test switch and read power meter.
- Daily check of nitrogen cylinder pressure. Visually check pressure gauge.
- Daily inspection of unit for damage and/or liquid leaks. Visually check unit for obvious leaks.
- Bi-weekly move each unit to a safe area, outside the hangar classified electrical area, and re-charge the on-board battery.

The only special tools required by the aircraft maintenance activity is extension cords for recharging the units.

CONCEPT OF ACTIVATION

The MAFFE will detect any fire event within its optical detector's field of view, 120 degrees (60 degrees to either side of the detector center line) and immediately activate its internal audible and visual alarm devices while simultaneously discharging the 120 gallons of AFFF solution as described above in a 90-degree pattern (45 degrees to either side of the detector center line). Discharge will be completed in approximately 115 seconds.

Facility occupants are expected to notify the fire department of the device activation.

Fire department responds and fights any fires outside the discharge pattern of the MAFFE.

HANGAR PORTABLE FIRE SYSTEMS ANALYSIS

EXECUTIVE SUMMARY

Options Considered

The Hangar Portable Fire System Analysis compares the cost of continuing with the current fixed AFFF fire systems in hangars with the cost of using a new portable AFFF system. The attached analysis compared the costs for the following scenarios:

- New construction: Build a new hangar with an AFFF system.
- Existing hangar with no AFFF: Install an AFFF system in an existing hangar.
- Existing hangar with water deluge system only: Add an AFFF system to a hangar having only a water deluge system.
- Existing hangar with AFFF system: Upgrade the existing fixed AFFF system.

Associated 25-Year Life Cycle Costs

The attached analysis of these options showed the following 25-year life cycle costs for an average 30,101-square-foot hangar. Because of the uncertainty of portable system costs, figures may vary by plus or minus 25 percent from those shown.

Option	Fixed AFFF	Portable AFFF
New hangar	$217,332	$391,234
Existing hangar with no AFFF	$242,886	$391,234
Existing hangar with water deluge system only	$114,940	$391,234
Existing hangar with AFFF	$93,065	$391,234

Even with a possible 25 percent variance in the portable system costs, the fixed system is less costly for all options.

Sensitivity Analysis of Portable AFFF Costs

A sensitivity analysis was performed on the portable AFFF costs which addressed the following options:

- Reduce the rebuild cost to 25 percent of new versus 50 percent of new used in the study.
  Portable life cycle cost = $370,756
- Reduce Operation and Maintenance on the portable system by 25 percent from $9,546 per hangar to $7,160 per hangar.
  Portable life cycle cost = $351,970
- Reduce the number of aircraft movements to once per week.
  Portable life cycle cost = $349,855

Even with a possible 25 percent variance in the portable system costs, the portable system is still more costly than the fixed options in all cases.

Conclusion

Several assumptions had to be made on the cost, operations, and maintenance of the portable systems. However, unless the assumptions are found to be grossly in error, the fixed AFFF system is the more economical choice for all options.

1. Introduction. This analysis will determine the cost of installing and maintaining fixed versus portable under wing AFFF fire suppression systems in AF hangars.

1.1. Alternatives Selected for Analysis. The study will compare the overall cost for the two systems based on the following scenarios:

- New construction: Build a new hangar with an AFFF system.
- Existing hangar with no AFFF: Install an AFFF system in an existing hangar.
- Existing hangar with water deluge system only: Add an AFFF system to a hangar having only a water deluge system.
- Existing hangar with an AFFF system: Upgrade the existing fixed AFFF system.

1.2. Assumptions.

1.2.1. Fixed AFFF. Hangar life is 25 years based on permanent construction. The fixed AFFF system life is also 25 years.

1.2.2. Portable AFFF. The system requires major rebuild at 10 and 20 years with 50 percent of the portable systems needing replacement at 20 years. There is one aircraft movement per day requiring repositioning of the portable units two times. It takes an average of 15 minutes per aircraft to reposition the units each time.

1.2.3. Facilities Requiring AFFF Systems. The following category codes (obtained from 1997 Air Force real property records) were identified as needing AFFF systems. Additionally, as a practical limit, only hangars 6000 square feet and larger were included.

Cat. Code	Total Area (ft^2)	Number	Average (ft^2)	1997 PRV*	Description
211111	15,847,229	387	40,949	$3,493,284,492	Maintenance Hangar
211116	4,483,772	33	135,872	$558,624,193	Depot Maintenance Hangar
211147	58,980	5	11,796	$10,958,036	ACFT/Weapons Calibration Shelter
211152	10,661,886	452	23,588	$1,524,038,280	General Purpose ACFT Maintenance
211159	4,251,142	166	25,609	$920,639,638	Corrosion Control Facility
211173	5,248,429	186	28,217	$1,073,816,703	Large ACFT Maintenance Dock
211174	224,047	6	37,341	$60,314,478	Consolidated ACFT Maintenance
211175	1,789,054	80	22,363	$359,629,377	Medium ACFT Maintenance Dock
211177	4,024,028	151	26,649	$791,473,221	Small ACFT Maintenance Dock
211179	4,042,104	216	18,713	$842,266,343	Fuel Systems Maintenance Dock
Total:	50,630,671	1,682	30,101	$9,635,044,761	

*Plant Replacement Value

1.3. Methodology:

- Determine the replacement and/or renovation cost for the fixed systems using the Air Force Parametric Cost Engineering System (PACES).
- Determine the operation and maintenance cost for the fixed systems from expert estimates.
- Determine the cost for installing, operating, and maintaining portable fire suppression systems from expert estimates.

2. Life Cycle Costs.

2.1. New Construction.

2.1.1. Using the Air Force Parametric Cost Engineering System (PACES), a Foam Below system cost $274,100 for a 40,000-square-foot hangar in 1997 dollars from a previous fire protection system cost study. The costs are average U.S. costs using the DoD 96 city average location and include all markups, typical contingencies of 5 percent for new construction, and 6 percent SIOH for a normal MILCON project. Adjusting this cost to an average size of 30,101 square feet (SF) for this study yields a cost of:

$$(\$274{,}100/40{,}000) \times 30{,}101 = \$206{,}267/\text{hangar } (30{,}101 \text{ SF})$$

2.1.2. Based on experts' analysis of required AFFF Below maintenance checks, the following hours are required per 30,101-square-foot hangar:

Quarterly – 2 people, 2 hours
Semi-Annual – 2 people, 4 hours
Annual – 2 people, 8 hours

Total = 2 quarterly + 1 semi-annual + 1 annual maintenance checks
= 2 people × 2 hours × 2 checks + 2 people × 4 hours + 2 people × 8 hours
= 32 hours per year

At $23.57/hour composite civilian labor rate from AFI 65-503, Table A27-1 for 1997,

O&M Cost = 32 hours per year × $23.57 per hour = $754 per year per hangar

2.1.3. All other parts of the Fire Protection system (e.g., sprinkler, water supply, alarms) will be equal for either a fixed or portable system.

2.1.4. The number of portable systems was estimated by laying out the spray pattern of the portable unit on a shadow of the aircraft (Exhibits 2 and 3) and determining the minimum number of portable units to cover the aircraft. The hangar square footage represents the clear zone required for the aircraft based on a 20-foot clear zone. The hangar square feet per unit is the hangar area required divided by the number of portable units. Following are the results:

Aircraft	F15	C130	KC135	Average
Wingspan	25	133	131	
Length	65	98	136	
Minimum Hangar Area	6825	23874	30096	
# Portable Units	2	6	8	
Shadow Area	953	3056	4275	
# Based on Criteria	2	4	5	
Hangar SF/Unit	3412.5	3979	3762	3717.833

These results do not support the concept package acquisition strategy of two units for the first 1500 square feet of aircraft shadow area and one unit for each additional 1000 square feet or portion of 1000 square feet. A more realistic requirement is two units for the first 1500 square feet and one unit for each additional 500 square feet or portion of 500 square feet of shadow area.

2.1.5. Adjusting the average hangar square feet per unit (3718 square feet per unit) to account for 10 percent extra portable units gives a coverage of 3380 square feet per unit. The initial cost is assumed to be $10,000 per unit.

Portable installed cost = $10,000 per unit ÷ 3380 square feet per unit = $2.9586 per square foot

Portable cost per hangar = 30,101 square feet × $2.9596 per square foot = $89,057 initial cost per hangar

2.1.6. Modify the base extinguisher maintenance shops for storage and handling of batteries and facilities for emergency showers and eyewash at the 196 Air Force locations with hangars that could use these portable AFFF systems. According to the PACES system, a 200-square-foot battery room would cost $46,525 average U.S. dollars in 1997. According to the table in paragraph 2.1.3, there is an average of 258,320 square feet (50,630,671 square feet total for 196 bases) of hangar space per base, which equals 8.6 hangars per base (258,320 square feet divided by 30,101 square feet per hangar). With an average of 8.6 hangars per location, the battery room cost is:

$46,525 ÷ 8.6 = $5,410 per hangar

2.1.7. Portable units require rebuilding at 10 and 20 years. Rebuild cost is assumed to be 50 percent of purchase cost, or $5,000 per unit. Fifty percent of the units cannot be rebuilt at the 20-year point.

Portable rebuild cost = $5,000 per unit ÷ 3380 square feet per unit = $1.4793 per square foot

Portable rebuild cost per hangar = 30,101 square feet × $1.4793 per square foot = $44,528 per hangar at the 10-year point

Portable rebuild cost per hangar = 30,101 square feet × $1.4793 per square foot × 50% = $22,264 per hangar at the 20-year point to rebuild 50% of the units

Portable cost per hangar = $89,057 × 50% = $44,528 per hangar at the 20-year point to replace 50% of the units

2.1.8. Based on the maintenance concept, the following maintenance is performed on the portable unit.

Test all units daily for battery power, adequate nitrogen cylinder pressure, and leaks. Assume 5 minutes per unit. With an average of 8.9 units per 30,101-square-foot hangar (30,101 square feet ÷ 3380 square feet per unit = 8.9)

Daily Maintenance = 5 minutes per unit per day × 8.9 units × 260 working days per year ÷ 60 minutes per hour = 192.83 hours per year

Every two weeks recharge the batteries on each unit. Unit must be moved outside the hangar classified electrical area. Assume 10 minutes per unit to move and set up, and 10 minutes to check the unit and move back into hangar.

Recharging = 20 minutes per unit × 26 times per year × 8.9 units per hangar ÷ 60 minutes per hour = 77.13 hours per year

With $23.57 per hour composite civilian labor rate (from AFI 65-503, Table A27-1 for 1997):

Routine maintenance cost = 270 hours per year × $23.57 per hour = $6,364 per year per hangar

Other maintenance includes replacing batteries, fixing flat tires, broken axles, and a five-year hydrostatic test. Assume another 50 percent to cover these items.

O&M cost = $6,364 $\times$ 150% = $9,546 per hangar

2.1.9. An additional operations expense is needed for the portable units to place them around the aircraft and remove them. It was assumed that 15 minutes would be required per aircraft movement to place the units and another 15 minutes to remove them. It was also assumed that there would be one aircraft movement per hangar per day for 260 working days per year. From the PRV study in paragraph 1.2.3, there were 1682 hangars in the category codes listed with an area of 6,000 square feet or larger, totaling 50,630,671 square feet, or an average size of 30,101 square feet.

Given:

260 working days per year
0.5 man hours per working day
$23.57 per hour composite civilian labor rate (AFI 65-503, Table A27-1 for 1997)

Operation Cost = 260 days $\times$ 0.5 man hours per day $\times$ $23.57 per hour = $3,064 per hangar

2.1.10. Maintenance people will have to be trained on proper operation and placement of the units. According to the PACES, there are approximately 75 people in a typical 30,101-square-foot hangar. Adjusting for office personnel not directly involved in aircraft maintenance, there are approximately 60 people per 30,101-square-foot hangar that would need training. Assume routine training would take one hour per year. Additional time would be needed by a trainer to give initial training to new people each month.

Training Cost = [(1 hour per year $\times$ 60 people) + (12 hours per year initial training)] $\times$ $23.57 per hour = $1,697 per year

2.2. Existing Hangar with No AFFF. Assume a Foam Below system is installed in the hangar, because according to Air Force criteria, a Water Above system must be installed, and if the hangar is 40 feet or less you can just add foam injection to the Water Above system to satisfy the current criteria. The cost for adding a foam system to an existing Water Above system is shown in paragraph 2.3.

2.2.1. Using PACES, adding a Foam Below system cost $308,269 for a 40,000-square-foot hangar in 1997 dollars. The costs are average U.S. costs using the DoD 96 city average location, and include all markups, typical contingencies of 10 percent for alteration, and 6 percent SIOH for a normal MILCON project.

2.2.2. Use the costs from paragraph 2.1.2 for operation and maintenance.

2.2.3. Foam Below Costs:

Construction cost = $308,269 per 40,000-square-foot facility = $7.707 per square foot
Construction cost per 30,101-square-foot hangar = $7.707 $\times$ 30,101 square feet = $231,988 per hangar

2.3. Existing Hangar with Water Deluge System Only.

2.3.1. Using PACES, adding an AFFF system to the water deluge system cost $137,144 for a 40,000-square-foot hangar in 1997 dollars. The costs are average U.S. costs using the DoD 96 city average location, and include all markups, typical contingencies of 10 percent for alteration, and 6 percent SIOH for a normal MILCON project.

2.3.2. Use the O&M cost for the Foam Below system in paragraph 2.1.2.

2.3.3. Adding a foam system to an existing water deluge system costs:

Construction cost = $137,144 per 40,000-square-foot facility = $3.4286 per square foot
Construction cost per 30,101-square-foot hangar = $3.4286 × 30,101 square feet = $103,204 per hangar

2.4. Existing Hangar with AFFF System (Upgrade Current AFFF).

2.4.1. With the current average age of Air Force hangars at 31.1 years, most systems will require renovation. Using PACES, renovating an AFFF system cost $107,885 for a 40,000-square-foot hangar in 1997 dollars. The costs are average U.S. costs using the DoD 96 city average location, and include all markups, typical contingencies of 10 percent for alteration, and 6 percent SIOH for a normal MILCON project.

2.4.2. Updating an existing foam system:

Construction cost = $107,885 per 40,000-square-foot facility = $2.6971 per square foot
Construction cost per 30,101-square-foot hangar = $2.6971 × 30,101 square feet = $81,185 per hangar

2.5. Twenty-Five-Year Life Cycle Costs. The economic analyses for these options are shown in Exhibit 4. The 25-year life cycle costs are shown below. Because of the uncertainty for the portable system costs, it may vary by plus or minus 25 percent from the values shown.

Option	Fixed AFFF	Portable AFFF
New hangar	$217,332	$391,234
Existing hangar with no AFFF	$242,886	$391,234
Existing hangar with water deluge system only	$114,940	$391,234
Existing hangar with AFFF	$93,065	$391,234

Even with a possible 25 percent variance in the portable system costs, the fixed system is less costly for all options.

4. Sensitivity Analysis. A sensitivity analysis was performed on the Portable AFFF costs using the following options:

- Reduce the rebuild cost to 25 percent of new versus 50 percent of new used in the study.
  Portable life cycle cost = $370,756
- Reduce Operation and Maintenance on the portable system by 25 percent from $9,546 per hangar to $7,160 per hangar.
  Portable life cycle cost = $351,970
- Reduce the number of aircraft movements to once per week.
  Portable life cycle cost = $349,855

Even with a possible 25 percent variance in the portable system costs, the portable system is still more costly than the fixed options in all cases.

4. Conclusion. Several assumptions had to be made on the cost, operations, and maintenance of the portable systems. However, unless the assumptions are found to be grossly in error, the fixed AFFF system is the more economical choice for all options.

THOMAS J. BURNS, P.E.
HQ AFCESA/CESM, DSN 523-6263, 2 Nov 98

4 Exhibits:
1. Category Code Descriptions
2. C-130 Shadow
3. KC-135 Shadow
4. Life Cycle Cost Analysis

HANGAR PORTABLE FIRE SYSTEMS ANALYSIS
Exhibit 1

Category Code Descriptions

CATCODE DESCRIPTION

211-111 *(HANGAR, MAINTENANCE)* - Facility designed to provide aircraft maintenance, repair, and inspection activities which require complete protection from the elements. Functional space areas include aircraft maintenance bays, administrative offices, storage, classrooms, and building support area. Construction cost includes concrete foundation and floor slab, insulated metal walls and roof on structural steel frame, AFFF fire suppression system, electrical, plumbing, heating, and air conditioning, motorized hangar doors on a structural track, with all components built to the aircraft size and configuration.

211-116 *(HANGAR, MAINTNENACE DEPOT)* - Facility designed to provide a completely covered space for aircraft undergoing programmed depot maintenance. Aircraft may be placed in static position for removal of components for routing through various shops for repair. Functional space areas include aircraft maintenance bays, material issue center, aircraft wash/preparation area, restrooms, break areas, administrative offices, and building support area. Construction cost includes concrete foundation and floor slab, structural steel frame, insulated metal walls and sloping metal roof, electrical, fire suppression system, fire alarm system, heating and ventilation. Approximate floor to ceiling height is 65 feet.

211-147 *(SHELTER, AIRCRAFT WEAPONS CALIBRATION)* - Facility designed to provide space for performing boresighting and harmonization on fire control and reconnaissance equipment.

211-152 *(SHOP, AIRCRAFT GENERAL PURPOSE)* - Facility designed to provide space for specialized maintenance, such as special fabrication and aerospace systems repair, both of which are specialized shops. Other functions include reclamation activities on wrecked or damaged aircraft. In addition to large maintenance bays, the facility typically includes administrative offices, tool cribs, locker space, and building support areas. Construction cost includes concrete foundation and floor slab, structural steel frame, insulated metal walls and sloping metal roof. Electrical, plumbing, AFFF fire suppression system, fire alarm system, heating and ventilation are also included in the cost of the facility.

211-159 *(AIRCRAFT CORROSION CONTROL)* - This facility may be a combination of covered washrack that accommodates one or more aircraft, a washrack to permit spot painting, a hangar for painting an entire aircraft, a contiguous or separate shop for corrosion control work on support equipment. Typically, the facility is a high bay hangar with extra large spans. Construction cost includes a 12" concrete slab on grade on concrete foundation, structural steel frame with sprayed on fire proofing, masonry walls and built-up roof. Motorized hangar doors, AFFF fire protection system, ultraviolet fire detection sensors, energy management system, wet pipe sprinklers, foam guns, high pressure washrack detergent system, underground fuel tanks, a 1000 gallon solvent detergent mixing tank, special boiler for aircraft washing, and a 2000 gallon oil/waste interceptor are also included. The facility has a compressed air system and an overhead monorail.

211-173 *(LARGE AIRCRAFT MAINTENANCE DOCK)* - Facility designed to provide protected space for the maintenance of large aircraft. They contain installed utility systems to include heat, plumbing, electric, and compressed air. AFFF fire protection, fire alarm panels, motorized hangar doors, and wet pipe sprinkler system are among other systems included in the cost of the facility.

211-174 *(CONSOLIDATED AIRCRAFT MAINTENANCE)* - Facility designed to provide protected space for the maintenance of aircraft. They contain installed utility systems to include heat, plumbing, electric, and compressed air. AFFF fire protection, fire alarm panels, motorized hangar doors, and wet pipe sprinkler system are among other systems included in the cost of the facility.

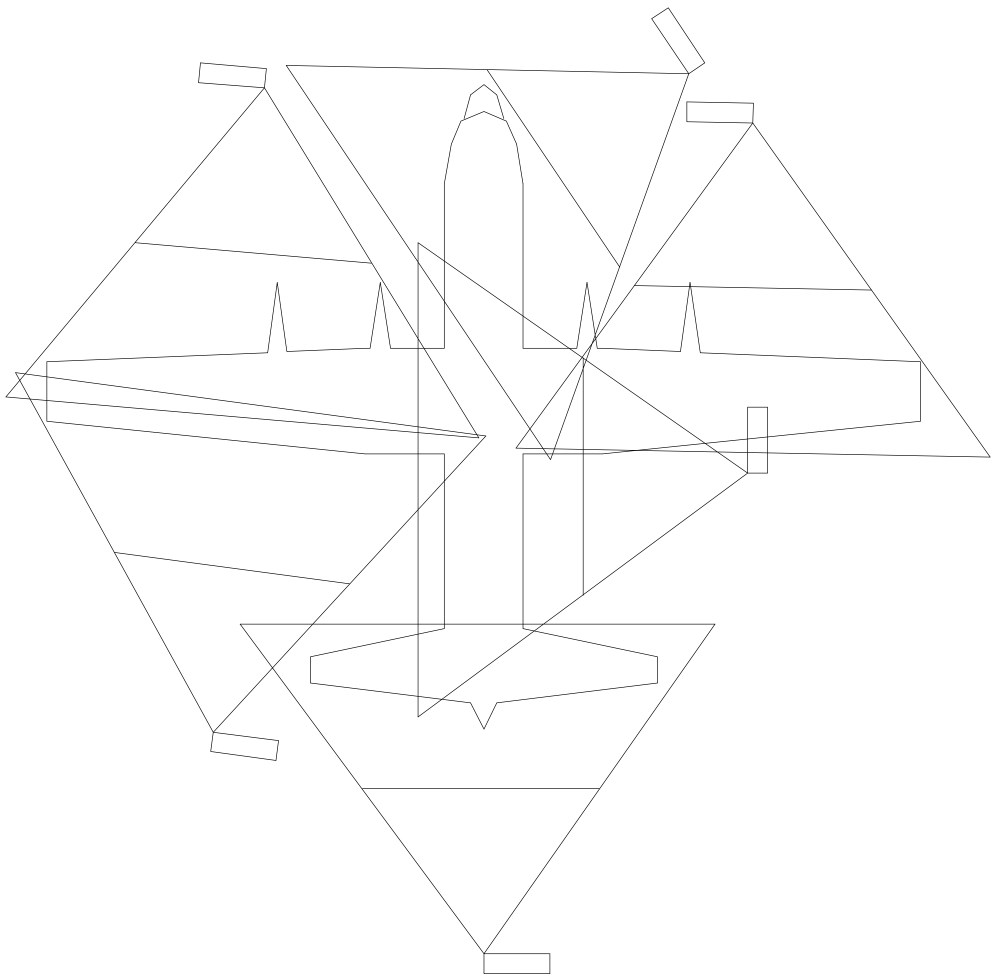
211-175 *(MEDIUM AIRCRAFT MAINTENANCE DOCK)* - Facility designed to provide protected space for the maintenance of medium sized aircraft. They contain installed utility systems to include heat, plumbing, electric, and compressed air. The facility is typically 35 feet high with a concrete foundation, 12" structural slab on grade, a structural steel frame, masonry walls with brick veneer, and built up roof. Motorized hangar doors and special overhead doors are included. Special systems include AFFF fire protection, wet pipe sprinkler system, fire alarm panels, and continuous trench drains in the work area.

211-177 *(SMALL AIRCRAFT MAINTENANCE DOCK)* - Facility designed to provide protected space for the maintenance of small aircraft. They contain installed utility systems to include heat, plumbing, electric, and compressed air. AFFF fire protection, fire alarm panels, motorized hangar doors and wet pipe sprinkler system are among the other special systems included in the cost of the facility.

211-179 *(FUEL SYSTEM MAINTENANCE DOCK)* - Facility designed to provide protected space for aircraft fuel system maintenance. Construction cost includes fume sensing and alarm system, mechanical ventilation, AFFF fire extinguishing system, and wash down drainage trenches. Other components include concrete foundation and floor slab, masonry walls, sloping metal roof, motorized hangar doors and track, heating, explosion proof electrical equipment, fire alarm panels, wet pipe sprinkler system, and plumbing. Space is provided for two aircraft maintenance bays, fuel cell repair area, shop space, and building support.

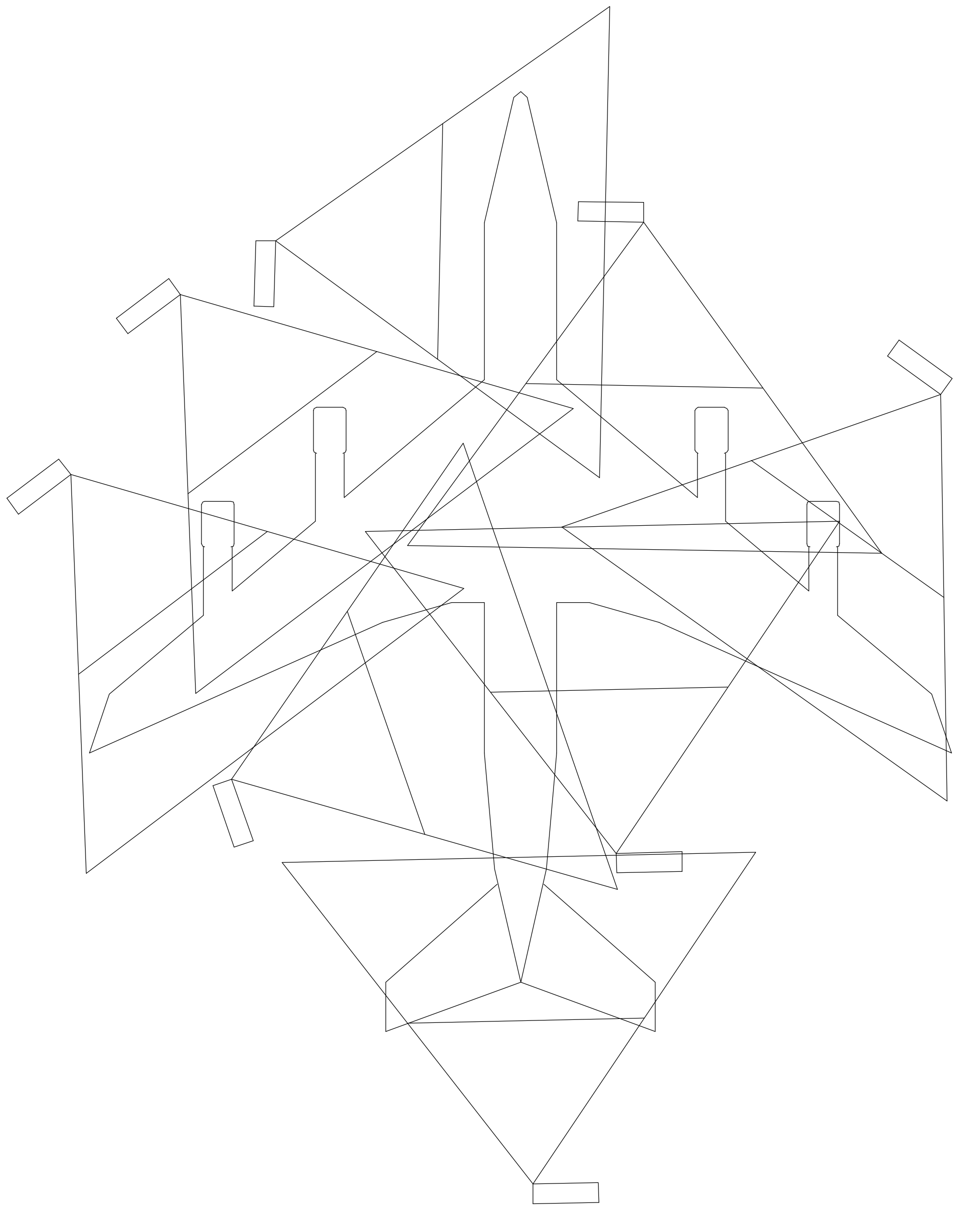
HANGAR PORTABLE FIRE SYSTEMS ANALYSIS
Exhibit 2

C-130 Shadow
(6 Portable Systems Required)



HANGAR PORTABLE FIRE SYSTEMS ANALYSIS
Exhibit 3

KC-135 Shadow
(8 Portable Systems Required)



HANGAR PORTABLE FIRE SYSTEMS ANALYSIS
Exhibit 4

Life Cycle Cost Analysis

Hangar Fire Systems
25-Year Life Cycle Analysis
Discount Rate 3.80%
(page 1 of 2)

Alternatives, Cost Components	Present Value	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Status Quo — Fixed AFFF Below													
Installation	204,924	212,711	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778
Total	217,332	213,488	778	778	778	778	778	778	778	778	778	778	778
Portable System													
Purchase Cost	88,477	91,839	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	5,579	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	—	—	—	—	—	—	—	—	—	—	45,919	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	391,234	112,172	14,754	14,754	14,754	14,754	14,754	14,754	14,754	14,754	14,754	60,674	14,754
Escalation from 1997 to 1999	1.031												
Add AFFF to Existing Hangar													
Installation	230,478	239,236	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778
Total	242,886	240,013	778	778	778	778	778	778	778	778	778	778	778
Add AFFF to a Water Deluge System													
Installation	102,532	106,428	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778
Total	114,940	107,206	778	778	778	778	778	778	778	778	778	778	778
Renovate Existing AFFF													
Installation	80,657	83,722	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778
Total	93,065	84,499	778	778	778	778	778	778	778	778	778	778	778

Hangar Fire Systems
25—Year Life Cycle Analysis
Discount Rate 3.80%
(page 2 of 2)

Alternatives, Cost Components	Present Value	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Status Quo — Fixed AFFF Below														
Installation	204,924	—	—	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778	778
Total	217,332	778	778	778	778	778	778	778	778	778	778	778	778	778
Portable System														
Purchase Cost	88,477	—	—	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	—	—	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	45,919	—	—	—	—	—	—	—	22,960	—	—	—	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	45,919	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	391,234	60,674	14,754	14,754	14,754	14,754	14,754	14,754	14,754	83,633	14,754	14,754	14,754	14,754
Escalation from 1997 to 1999	1.031													
Add AFFF to Existing Hangar														
Installation	230,478	—	—	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778	778
Total	242,886	778	778	778	778	778	778	778	778	778	778	778	778	778
Add AFFF to a Water Deluge System														
Installation	102,532	—	—	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778	778
Total	114,940	778	778	778	778	778	778	778	778	778	778	778	778	778
Renovate Existing AFFF														
Installation	80,657	—	—	—	—	—	—	—	—	—	—	—	—	—
O&M	12,408	778	778	778	778	778	778	778	778	778	778	778	778	778
Total	93,065	778	778	778	778	778	778	778	778	778	778	778	778	778

Sensitivity Analysis Results
(page 1 of 2)

Alternatives, Cost Components	Present Value	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Reduce rebuild to 25% of purchase price													
Portable System													
Purchase Cost	88,477	91,839	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	5,579	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	20,479	—	—	—	—	—	—	—	—	—	—	22,960	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	370,756	112,172	14,754	14,754	14,754	14,754	14,754	14,754	14,754	14,754	14,754	37,714	14,754
2. Reduce O&M cost 25%													
Portable System													
Purchase Cost	88,477	91,839	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	5,579	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	—	—	—	—	—	—	—	—	—	—	45,919	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	—	—	—	—
O&M	117,826	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	351,970	109,712	12,294	12,294	12,294	12,294	12,294	12,294	12,294	12,294	12,294	58,213	12,294
3. Reduce movement to once per week per hangar													
Portable System													
Purchase Cost	88,477	91,839	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	5,579	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	—	—	—	—	—	—	—	—	—	—	45,919	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	10,085	632	632	632	632	632	632	632	632	632	632	632	632
Training	26,888	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	349,855	109,644	12,226	12,226	12,226	12,226	12,226	12,226	12,226	12,226	12,226	58,146	12,226

Sensitivity Analysis Results
(page 2 of 2)

1. Reduce rebuild to 25% of purchase price

Alternatives, Cost Components	Present Value	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Portable System														
Purchase Cost	88,477	—	—	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	—	—	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	20,479	—	—	—	—	—	—	—	—	11,480	—	—	—	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	45,919	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	370,756	14,754	14,754	14,754	14,754	14,754	14,754	14,754	14,754	72,154	14,754	14,754	14,754	14,754

2. Reduce O&M cost 25%

Alternatives, Cost Components	Present Value	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Portable System														
Purchase Cost	88,477	—	—	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	—	—	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	—	—	—	—	—	—	—	—	22,960	—	—	—	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	45,919	—	—	—	—
O&M	117,826	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384	7,384
Operations	50,426	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Training	27,926	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	351,970	12,294	12,294	12,294	12,294	12,294	12,294	12,294	12,294	81,173	12,294	12,294	12,294	12,294

3. Reduce movement to once per week per hangar

Alternatives, Cost Components	Present Value	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Portable System														
Purchase Cost	88,477	—	—	—	—	—	—	—	—	—	—	—	—	—
Battery Room	5,375	—	—	—	—	—	—	—	—	—	—	—	—	—
Rebuild Cost	40,958	—	—	—	—	—	—	—	—	22,960	—	—	—	—
Rebuild Replace Cost	20,982	—	—	—	—	—	—	—	—	45,919	—	—	—	—
O&M	157,090	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844	9,844
Operations	10,085	632	632	632	632	632	632	632	632	632	632	632	632	632
Training	26,888	1,750	—	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total	349,855	12,226	10,476	12,226	12,226	12,226	12,226	12,226	12,226	81,105	12,226	12,226	12,226	12,226

ANALYSIS OF QUESTIONNAIRE

AIRCRAFT HANGAR FIRE SUPPRESSION SYSTEMS OPERATIONAL REQUIREMENTS PARAMETERS

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
1. Class A Fire Effectiveness Extinguish solid combustibles (wood, paper, composite materials, fiberglass, plastics, vinyl)	6	5/7 10/5	8	10/12
2. a. Class B Fire Effectiveness Extinguishes flammable and combustible liquids spill fires (pools on the floor) (jet fuel, avgas, diesel fuel, gasoline, lubricants)	10	10/20	10	10/22
b. Class B Fire Effectiveness Extinguishes flammable and combustible liquids three-dimensional fires (sprays, leaks flowing & dripping,) (jet fuel, avgas, diesel fuel, gasoline, lubricants)	10	10/19	10	10/22
3. Class C Fire Effectiveness Extinguishes Class A & B fires involving energized electrical equipment.	7	10/9 5/5	9	10/16
4. Class D Fire Effectiveness Controls combustible metals fires (magnesium, lithium, titanium, uranium, & alloys of these meals)	6	NDA (no definitive answer. Answers spanned the spectrum of available options)	8	10/14
5. a. Persistence Extinguishes fire without fire department intervention.	8	10/9 7/4	8	10/10 8/7
b. Persistence Extinguishes fire but requires fire department for final clean up	8	10/6 7/6 8/4	8	10/13 8/6
c. Persistence Controls fire but requires fire department for final extinguishment	9	10/13	8	10/12 8/5

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
d. Persistence Control fire in select areas (under aircraft) but requires fire department to control complete fire and extinguish fire (fire freely burns outside select areas until fire department arrival).	6	10/7 5/5	7	10/12 5/5
e. Persistence Fire department to control and extinguish fire (fire freely burns until fire department arrival).	4	10/6 0/7	5	10/7 5/6
6. a. Health Effects/Agent Toxicity Effect on personnel of unburned agent (during accidental release/ servicing/ no fire).	8	10/13	10 1	10/21
b. Health Effects/Pyrolysis Toxicity Effect on personnel of decomposed agent (during actual fire events).	8	10/14	10	10/21
7. Egress Impact Agent impact on safe egress from the fire area (visual - ability of personnel to see, stability - ability of personnel to maintain a safe footing).	9	10/16	10	10/22
8. a. Environmental Impact/ Agent Production Environmental effects from the manufacture of the agent.	7	10/8 5/4	7	10/8 8/6 all other answers evenly distributed
b. Environmental Impact/ Agent Environmental effect from agents when no fire exists (accidental release, maintenance).	7	10/8 5/5	8	10/10 8/7
c. Environmental Impact/ Agent Pyrolysis Environmental effect from the agents and decomposition of the agent during fire events	7	10/6 5/5 7/4	7	10/7 8/8 7/4

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
d. Environmental Impact/ Wash Down Effluent Environmental effect from the wash down of agent effluent for fire and no fire scenarios.	8	10/9 8/5	8	10/9 8/6 7/4
9. a. Electrical Conductivity Risk of shorting out electrically charged circuits within the hangar.	7	10/7 all other answers evenly distributed	9	10/17
b. Electrical Conductivity Risk of shorting out electrically charged circuits within the aircraft.	7	10/6 7/5 8/3	9	10/18
10. a. Agent Compatibility Agent will have no adverse effect on aircraft surfaces.	8	10/10 all other answers evenly distributed	9	10/17
b. Agent Compatibility Agent will have no adverse effect on aircraft components.	8	10/9	10	10/18
c. Agent Compatibility Agent will have not adverse effect on support and other equipment in the hangar.	6	NDA	8	10/12 all other answers evenly distributed
11. a. Pyrolysis Products Compatibility Products will have no adverse effect on aircraft surfaces.	8	10/9 all other answers evenly distributed	9	10/18
b. Pyrolysis Products Compatibility Products will have no adverse effect on aircraft components.	7	10/9 5/4	9	10/19
c. Pyrolysis Products Compatibility Products will have not adverse effect on support and other equipment in the hangar.	6	NDA	8	10/11 8/4 all other answers evenly distributed
12. Organic Maintenance Capability Air Force has an in-house capability to maintain and service components.	7	10/8 9/4	6	10/8 6/4 all other answers evenly distributed

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
13. a. Manpower Requirements – Positioning Aircraft maintenance personnel positioning units around aircraft and moving units to permit aircraft movements.	9	10/12	8	10/10 8/5 5/4
b. Manpower Requirements – Positioning Aircraft maintenance personnel positioning units around aircraft and moving units to permit aircraft movements. Indicate the maximum time acceptable per aircraft movement for movement and repositioning of fire protection devices. _________ minutes	13	10/10 5/4	10	NDA
14. a. Manpower Requirements – Daily inspection Aircraft maintenance personnel daily ensure each unit is correctly positioned and test battery condition.	8	10/14	9	10/14
b. Manpower Requirements – Daily Inspection Indicate the maximum time acceptable per aircraft movement for movement and repositioning of fire protection devices. _________ minutes	12	NDA	10	NDA
15. a. Manpower Requirements – Recharging Aircraft maintenance personnel recharge unit batteries bi-weekly.	29	10/12	11	10/15 9/3

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
b. Manpower Requirements – Recharging Aircraft maintenance personnel recharge unit batteries bi-weekly. Indicate the maximum time acceptable per recharge of fire protection device batteries. _________ minutes	61	Extreme range of answers – from 0 to 480	23	NDA
16. a. Manpower Requirements – Maintenance & Repair Fire department personnel or contract deliver units to hangars and conduct periodic maintenance, repair and servicing.	19	10/13	9	10/15 8/6
b. Manpower Requirements – Maintenance & Repair Indicate the maximum time acceptable per aircraft movement for movement and repositioning of fire protection devices. _________ minutes	25	Extreme range of answers – from 0 to 240	12	NDA
17. Acquisition Costs The procurement and any required support equipment. /tools costs (base O&M funded).	8	10/10 all other answers evenly distributed	8	10/13 8/4
18. Life Cycle Costs Acquisition costs plus the costs to operate {including manpower}, maintain, and dispose of the units.	8	10/10 all other answers evenly distributed	8	10/15
19. Automatic Activation Required A hands-off capability that requires no personnel in the activation sequence.	9	10/15	9	10/19
20. a. Manual Activation Required Personnel must activate the system.	5	10/6 all other answers evenly distributed	6	NDA

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
b. Manual Activation Required Personnel must be able to activate the system without reliance on any power source.	9	10/18	9	10/19
21. Manual Abort Required Personnel must be able to prevent and or cut off system discharge.	9	10/17	10	10/21
22. Sensor Required Sensor to detect a fire event (can also be used to activate the device).	10	10/19	9	10/15
23. a. Notification Required – Fire Department Every fire event must cause an automatic notification of the fire department.	9	10/20	9	10/20
b. Notification Required – Hangar Every fire event must cause an automatic activation of the building fire alarm devices.	10	10/22	10	10/21
24. Back-up Activation Power Source In event of failure of the primary system activation power source, a redundant or back-up power source is important.	9	10/17	9	10/18
25. Space Claim The floor space (footprint) that the device occupies is important.	9	10/11	9	10/18
26. Protection of Assets Prioritize the following items - use the same 10 point weighting scale assigning 10 point to the highest priority and lower points to each lower priority. Points assigned do not have to be consecutive.				
a. Personnel	10	10/12	10	10/26
b. Incident Aircraft Aircraft in contact with flames or directly over flames.	9	10/21	9	10/14 9/10

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
c. Adjacent Aircraft Aircraft not in contact with flames but being heated by radiation and convection of thermal energy from a fire	9	10/9 8/9	**9**	10/12 9/6 8/6
d. Support Equipment	**7**	NDA	**7**	NDA
e. Hangar	**8**	10/7 6/6	**8**	8/10 10/6 7/4
f. Mission Continuity Ability to continue the generation and repair of aircraft in a given hangar	**8**	10/10 9/4 5/4	**8**	NDA
27. a. Response Time What is the maximum acceptable time for a fire protection system to control a fire which has exceed the size it may be extinguished with a portable extinguisher (including a flight line 150 Halon 1211 extinguisher)? 0 – 30 Seconds 31 – 60 seconds 1-2 minutes 2-3 minutes 3-4 minutes 4 – 5 minutes over 5 minutes	**2**	NDA	2	NDA
b. Response Time What is the maximum acceptable time for a fire protection system to extinguish a fire which has exceed the size it may be extinguished with a portable extinguisher (including a flight line 150 Halon 1211 extinguisher)? Use same codes as item 27a.	3	3/10 4/6	3	NDA

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
28. Acceptable Level of Damage In keeping with your answer to "response time" what is the acceptable level of damage, in percent loss to:				
a. Personnel	0	1/22	0	NDA
b. Incident Aircraft Aircraft in contact with flames or directly over flames.	8	1/7 10/7	18	NDA
c. Adjacent Aircraft Aircraft not in contact with flames but being heated by radiation and convection of thermal energy from a fire	4	1/7 5/4 10/5	7	0/11 10/5
d. Support Equipment	16	10/6 1/5	26	NDA
e. Hangar	5	5/5 1/10	23	NDA
f. Mission Continuity Ability to continue the generation and repair of aircraft at a given installation	18	10/6 5/4 1/7	13	0/12 10/3
29. Normal Ambient Temperature Range What is the typical winter-summer temperature extreme at your installation (in degrees F)?	90 15	Data extremely suspect – broad variation in reported temperatures at the same location	91 4	Data extremely suspect – broad variation in reported temperatures at the same location
Is it possible for the hangar areas to be exposed to temperatures below 32 degrees F for more than 30 minutes? YES = 1 NO = 2	1	1/19	1	1/21 2/5
Are cold (minus 30 degrees F) ambient conditions a requirement? Is it possible for the hangar areas to be exposed to temperatures to –minus 30 degrees for more than 15 minutes?	2	1/8 2/14	2	1/7 2/18

OPERATIONAL PARAMETER	CE Av.	CE High Score Answers 22 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)	LG Av.	LG High Score Answers 26 Completed Questionnaires (Answer/Number of Respondents Selecting that Answer)
Are arctic (minus 30 degrees F) ambient conditions a requirement? Is it possible for the hangar areas to be exposed to temperatures arctic temperatures for more than 15 minutes?	2	1/5 2/17	2	2/26
Are equatorial (plus 160 degrees F) ambient conditions a requirement? Is it possible for the hangar areas to be exposed to temperatures to equatorial temperatures for more than 30 minutes?	2	2/21	2	2/25
30. OTHER **ADD ANY ADDITIONAL FACTORS YOU FEEL CRITICAL TO THIS ISSUE.**		Attached		Attached

CONCERNS EXPRESSED BY SURVEY RESPONDENTS

ID	COMMENT	Rating, If Rated
2	Quantity of units needed to support aircraft parking spots	
3	Aircraft strobe light maintenance could activate the sensors	10
3	Welding arc could activate the system	5
3	12 volt batteries constitute a hazard in a fuel dock and corrosion facilities because of explosion proof equipment requirements	10
3	Excessive maintenance and inspection requirements on the unit	5
4	Bldg 437 DK5 is the ISO inspection facility. We have a lot of equipment and personnel in the hangar during an inspection. The 25-ft clear zone may be hard to maintain. Application of this equipment would not be practical in our facility.	
5	The MAFFE operates with a 12-volt battery which introduces a spark-producing agent in a Class I Div 2 hazardous area.	
5	Use of the MAFFE places a greater burden on aircraft maintainers, who would need to become skilled and knowledgeable in the daily and operator maintenance of the unit. From an aircraft mechanic's point of view, this can't be better than the current system.	
5	Current systems allow for complete confidence in fire extinguishing capability, regardless of the size/type aircraft; the MAFFE system must be "customized" to each aircraft.	
5	Assuming the MAFFE is to replace current hard-mounted foam cannons for Group I hangars, then the provided MAFFE specs do not seem adequate IAW NFPA 409, Standard on Aircraft Hangars, 1995 edition. This Standard, in chapter 3-3 for Supplementary Protection Systems, calls out for the following: a. For AFFF concentrate, the minimum application density shall be 0.10 gpm of foam solution per sq ft (ref: 3-3.5.4) b. The quantity of foam liquid concentrate shall be sufficient for a 10-minute discharge (ref: 3-3.5.5)	
8	This application could also be utilized for Hot Refueling operations, in lieu of a standby fire truck.	
12	Due to limited hangar space it would not be practical to move the units and meet the 25-ft. minimum clearance.	
12	Are the recharging units (elec.) certified for fuel and paint vapor areas?	
12	Would the system be activated by a diesel-powered piece of equipment? If so what is a safe distance? This could limit maintenance ability.	
12	Are the units considered out of service while recharging the batteries?	
12	We could not meet the 25 ft requirement	
12	Aircraft are parked in the center of hangars and would not be in the protected areas. We could not mark the floors with patterning or application zone discharge areas. Too many aircraft.	
12	For recharging purposes can the units be left outside exposed to the elements? We do not have indoor areas to accomplish this.	

ID	COMMENT	Rating, If Rated
13	During peak maintenance periods there are as many as 16 to 18 aircraft in our hangars. With this many aircraft and associated equipment around the aircraft the 25” to 50’ practical protection area for the MAFFE will be impossible to maintain.	
13	There is not enough room in the hangars here to provide two MAFFE for each parking position. The practical area of protection of 1350 sq ft cannot be accomplished due to many obstructions.	
16	Compared with the systems that are in hangars at his time, we do not feel this unit would improve on the fire protection. This unit would bring not only extra cost to procure and maintain but also extra workload to both the Fire Dept and Aircraft Maintenance due to the daily upkeep, inspection, and repair, reserving and repositioning. With the drawdown of manpower within the Air Force and budget cuts, it would be unwise to replace what systems we have at this time.	
18	Explosion Proof Requirements: must meet T.O. 1-1-3 requirements for operation in an aircraft fuel cell.	10
18	Rate of Suppression: As identified in ETL 98-7, 98-8, and NFPA 409 standards.	10
18	Storage Capacity: IAW ETL and NFPA standards.	10
18	Area of Suppression: Ability to cover topside of aircraft from on the ground	10
18	Not enough functional data to properly evaluate equipment. No MSDS.	10
18	Cannot be UVIR as per ETL 98-7, 98-8	
18	Do not want as a prerequisite; suitable as an optional capability	
22	We currently have Halon bottles. The inspection requirements are simple, there are not batteries to maintain, you can direct the Halon at the source of the fire, and the bottle does not automatically go off without human input. There is also no mess to clean up. The automatic system would be useful at times when nobody is on duty, but we have no way at this time to evaluate the corrosiveness or health hazard possibilities of the agent.	
23	All of our hangar facilities are equipped with AFFF systems. We have no need to replace existing operational systems. We feel that this would probably be wasteful.	
24	Due to the amount of room in our hangar and the manning we have available, we must have a self-contained unit that is hands free and worry free. Our present unit is basically maintenance free as far as the aircraft maintenance people are concerned. This system would not fit in our present hangar.	
26	JP-8 reduced flash point. Within 6 months JP-8 +100 will reduce flash points again.	9
26	Current Halon and CO^2 methods are adequate, assuming JP-8 +100.	9
26	Host tenant agreements for Maintenance/Servicing	8
26	Having more training and labor added to the unit personnel is unacceptable.	10

ID	COMMENT	Rating, If Rated
36	All dock areas have personnel housed there in shops and dispatched there as a part of normal maintenance repair team. These personnel will be exposed when hangar fires occur. Due to the fact that aircraft are routinely parked in these same buildings for repair and a variety of other things, fire becomes even more critical because of the jet fuel contained in these aircraft. It is VERY IMPORTANT that fire prevention is practiced and fires contained quickly in the event that they occur. Equipment must be capable of extinguishing fires rapidly or have the ability to control fires until the Fire Department arrives with sufficient equipment.	10
37	Exact quote of #36.	10
38	Aircraft strobe light maintenance could activate the sensors	10
38	Welding arc could activate the system	5
38	12 volt batteries constitute a hazard in a Fuel Dock and corrosion facilities because of explosion proof equipment requirements	10
38	Excessive maintenance and inspection requirements on the unit	5
41	This unit, MAFFE, wouldn't be helpful to us because our aircraft is parked in the same position. Also, more aircraft will be assigned to squadron and floor space isn't available for these types of extinguishers. We don't have the personnel to maintain, inspect, recharge batteries, move units during an (rest of comment lost off bottom of fax page)	
42	Depot funded	10
42	Manpower maintenance of units	10
42	Maintenance/maintained contract	10
44	Applicable in facilities housing maintenance processes on fueled aircraft. May not be applicable in fuel cell repair facilities where aircraft are defueled.	
46	Environmental issues need to be addressed by someone in CEV. This needs to be rated by someone more knowledgeable on air/water requirements.	
46	Aircraft maintainers would be a better source for input on items 10 and 11.	
46	Concept as stated is for fire departments to maintain the MAFFE in the same manner as portable and flightline fire extinguishers. This will be a tremendous addition to an already heavy workload. There is no manning for extinguisher maintenance and most departments have contracted this work out. To expect fire departments to take on this additional work without additional manpower is unreasonable.	
46	I question the use of the MAFFE on large frame aircraft. The Practical Protection Area appears small, which will require multiple units, and additional time for maintainers to position the MAFFE. If the application is to only provide fire coverage for an isolated task specific area then the MAFFE may prove to be effective.	
46	The maintenance community must address their manpower requirements. These units should be easily set up. If it takes too long to deploy the units, they may not be used when only a quick fix is needed on an aircraft.	
46	No response is provided for item 28, Acceptable level of Damage. This should be determined by the authority having jurisdiction (AFCESA) not the fire chief.	
53	WE DO NOT WANT THIS!!	

ID	COMMENT	Rating, If Rated
54	We have a good system installed in Dock 6 and it's paid for	8
54	Welding arc or aircraft strobe could activate the system	8
54	12 volt batteries constitute a hazard in a Fuel Dock and corrosion facilities because of explosion proof equipment requirements	10
54	Excessive maintenance and inspection requirements on the unit	8
54	Effect of paint, paint over-spray, chemicals, soap, wash water and aircraft wash process	10
54	Any restrictions imposed or ability to position powered lift equipment used in paint and wash process.	
55	It is generally agreed (throughout the command) that many of the existing suppression system problems can be solved with a greater emphasis on maintenance, and the qualifications of maintainers.	
56	10 % backup is not a trouble as 20 % backup should be on hand. Also, all equipment to service the units must be in place along with training prior to putting units in service.	